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# Effects of Traditional versus Electronic Note Taking in a High School Biology Classroom

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EFFECTS OF TRADITIONAL VERSUS ELECTRONIC NOTE TAKING IN A HIGH SCHOOL BIOLOGY  
CLASSROOM

A Thesis

Submitted to the Graduate Faculty of the  
Louisiana State University and  
Agricultural and Mechanical College  
in partial fulfillment of the  
requirements for the degree of  
Master of Natural Science

in

The Interdepartmental Program in Natural Sciences

by  
Chelsea Ann Duhon  
B.S., Louisiana State University, 2012  
August 2015

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## **ABSTRACT**

This study investigated the effect of traditional and electronic note taking on student achievement and engagement in a Louisiana high school biology classroom. Over a 20-week period, traditional students (n= 58) took notes using pencil and paper and electronic note takers (n=46) used their laptop computers. Each group of students was given identical pre and posttests covering three units and a practice End of Course exam. Normalized learning gains were compared for each unit and suggest there is no significant difference in academic achievement between the traditional note takers and the electronic note takers. An attitudinal survey was also administered and indicated that both electronic and traditional note takers preferred taking notes traditionally. Observations conducted by the teacher indicated a low occurrence of off task behavior; there were no significant differences between note taking groups. Results that were self-reported by the students show greater off task occurrences, especially within the electronic group. Teachers should carefully consider integrating technology into the note taking process. Since electronic note taking affects student engagement, but does not impact student achievement, allowing students the freedom to choose whichever method they prefer may positively impact classroom culture.

## INTRODUCTION

Educators have a very important job to do: they teach. The question of how students learn best is often a topic of conversation within schools and teacher preparation programs. Educators are being held to higher standards and accountability within the profession is at an all time high. Schools, and in some cases, individual teachers, are being rated based on student performance on ever changing state mandated tests. There has been a clear shift from multiple-choice assessments led by No Child Left Behind (NCLB) to Common Core and PARCC assessments where students are required to write and apply content knowledge across disciplines (Conley, 2015). Some state mandated tests, like an End of Course Exam (EOC), require students to pass to graduate, and the ACT, once known as the American College Test, determines college and career readiness. Educators around the country are asking themselves what they can do to better prepare their students for the future.

Studies support many different types of cognitive strategies for how people learn (Dunlosky et al., 2013; Bransford et al., 2001; Billing, 2007; Lemov, 2010,). One essential cognitive learning strategy is note taking. This strategy has been successfully implemented across all disciplines and with students of all ages. For almost 90 years the education community has indicated the importance of note taking highlighting its positive effects on student achievement (Crawford, 1925; Fisher and Harris, 1974; Hartley and Davies, 1978; and Kiewra, 1985; Marzano et al., 2001).

Traditionally note taking is defined as the process of capturing key ideas and concepts. These can be in the form of textual outlines, guided notes, concept maps and webs. DiVesta and Gray (1972) divided the process of note taking into two specific functions: the encoding function, which is the process of recording the notes, and the storage function, which is the process of reviewing the notes. Across 24 studies, reported by Hartley (1983) and Kiewra (1985), the process of integrating both the storage function and the encoding function, together rather than either function alone, has been the most beneficial note taking mechanism for boosting content retention across disciplines.

The encoding function involves the process of recording content. This recording process can be in the form of concept maps, guided notes, outlines, recorded verbatim or summarized from the instructor, or any other written form of the presented content. The process of encoding content allows for facilitation of learning, even in the absence of review. A meta-analysis of over 100 studies of note taking across multiple disciplines and grade levels by Beesley and Aphthorp (2010) illustrates a large overall effect, a Hedges'  $g=0.90$ , demonstrating a positive effect of note taking on performance. In these studies, students were asked to take notes while listening to a lecture while another group was asked to only listen to the lecture. Neither group reviewed the material. Students who took notes performed on the final assessments than students who did not take notes, indicating the function of encoding within note taking is a primary cognitive strategy to improve student performance.

The storage function of note taking is the process of reviewing notes as a mechanism to facilitate retention. The storage function can be applied to any encoded notes, regardless of the mechanism of encoding. The validity of the storage function has been established by multiple studies measuring the performance of students who studied notes versus students who did not

study notes (Kiewra, 1989). There are various methods of storing information, or studying, and there is an overwhelming amount of information indicating the storage function is beneficial to student achievement (King, 1992; Kiewra, 1985a).

The storage function allows for review of the material while the encoding function describes the cognitive process of taking notes. Although the application of the storage function is more beneficial than the encoding function alone, encoding a complete note set is essential for storage and therefore essential to increase student achievement (Carter and Van Matre, 1975; Fisher and Harris, 1974; Kiewra, 1985; Rickards and Friedman, 1978). This indicates the necessity for both facets of note taking, the storage and encoding function, used together to boost student achievement (Hartley, 1983; Kiewra, 1985; Kiewra, 1989).

By 2008 public schools in the United States had an average of 189 instructional computers on site, which was an increase from only 72 instructional computers in 1995 (U.S. Department of Education) (Figure 1). More computers on each site meant that the student to computer ratio across the country decreased. By 2008, there was one computer for every three students. This increase in available technology made it possible for teachers to integrate projects and activities that involved the use of student computers, shifting the classroom culture from teacher centered to student centered (Figure 2). In recent years, many schools are electing to participate in a 1:1 ratio where each student and teacher is in possession of a laptop. These investments are made for a variety of reasons, some including preparation for future jobs, increased exposure for low income students, and even classroom reform, specifically to make students and teachers more effective (Zucker and Light, 2009). Apple, Inc, in collaboration with many universities, research institutions, and teachers, has contributed to the 1:1 program and has conducted studies with hundreds of students and teachers across the country to evaluate the benefits of a 1:1 ratio. The Apple Classrooms of Tomorrow Initiative has concluded that these 1:1 programs can significantly increase the potential of student learning and engagement (Dwyer, 1994), however these findings may not be valid since this study was not independently tested. Because of a increase in available technology and state and district initiatives pushing for teachers to incorporate technology into their curricula and instruction, it is increasingly important to evaluate the effects of using computers as a metacognitive learning strategy.

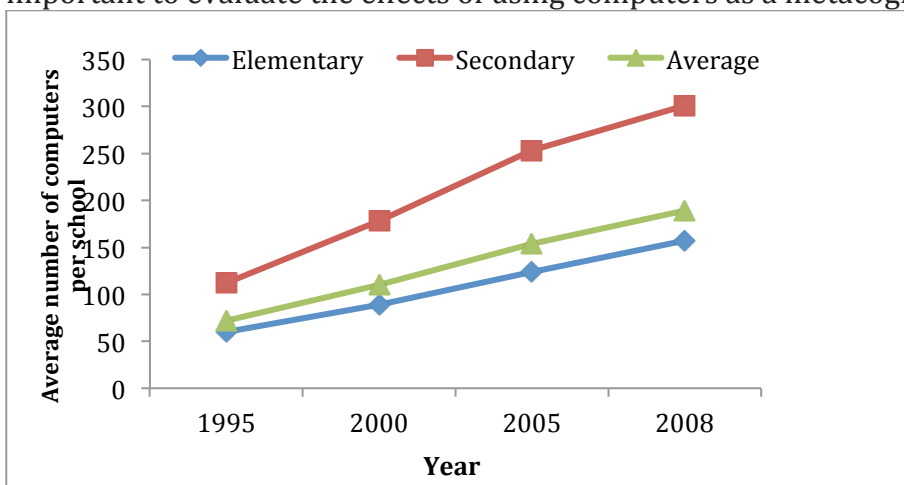


Figure 1. Average number of computers for instructional purposes, in U.S. public schools from 1995-2008 (U.S. Department of Education).

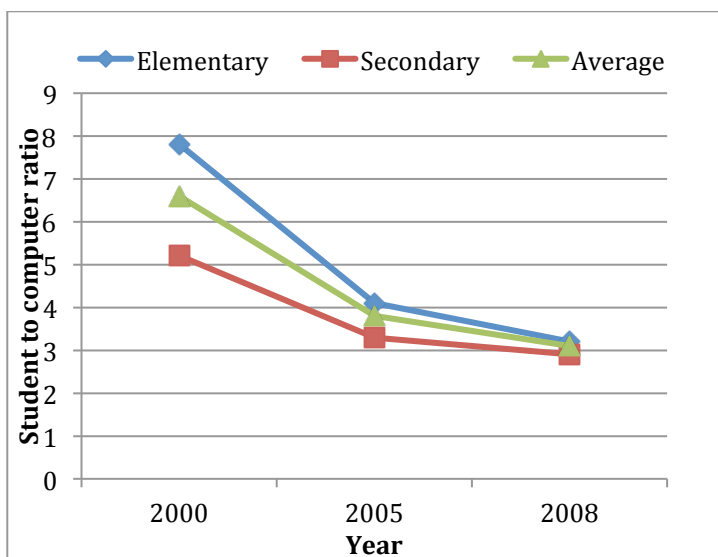


Figure 2: Ratio of students to instructional computers, in U.S. public schools from 2000-2008 (U.S. Department of Education).

Students and teachers agree that computers can help promote student engagement, however much of the literature on implementing technology within the classroom shows conflicting impacts on student achievement. On one hand, the use of computers within the classroom provides students with access to a variety of supplemental resources, promotes active learning (Alavi, 1994), and increases student perception of engagement (Driver, 2002). While other sources show students become more distracted and are more likely to multitask in class, leading to lower comprehension of the material (Sana et al., 2013; Wood et al, 2012). This lack of consensus in current studies evaluating the effectiveness of computer use within the classroom warrants additional review.

A recent study by Oppenheimer and Mueller (2014) examined the effects of taking traditional notes versus laptop notes. The study integrated the traditional encoding function with the idea of electronic encoding. Part one of the study showed that taking notes using pencil and paper had the same effect as taking notes using a computer when students were tested on factual knowledge. It did not have the same effect when students answer conceptual questions. Students who took notes electronically do not perform as well as traditional note takers when conceptual understanding is assessed.

The by Oppenheimer and Mueller (2014) showed that the electronic note takers encode more notes than the traditional note taker, and of those notes, an average of 14.6% were verbatim for the electronic encoder compared to an average of 8.8% for traditional encoders. Although participants who encode more notes perform better, the best indicators of performance are encoded notes with less verbatim overlap. This study highlights the effects of laptops increasing quantity of notes during encoding but also demonstrates that this mechanism is not enough to increase higher metacognitive learning.

In part two of the study, students in the electronic note taking group were asked to take notes as they normally do, but to try to avoid transcribing the lecture word for word since verbatim notes seem to inhibit student achievement. The results showed factual learning did not change between the two groups but conceptual understanding improved in the traditional note taking



group. The note taking intervention for the electronic group was determined to be unsuccessful since the electronic notes continued to be a verbatim copy of the lecture; the note set from study one was not statistically different from the note set in study two (Oppenheimer and Mueller, 2014).

In part three of the study the students were broken into four groups. Two groups were traditional note takers and two groups were electronic note takers (Oppenheimer and Mueller, 2014). One group from traditional and one group from electronic were allowed to study their note sets for 10 minutes before being assessed while the other groups were assessed immediately following taking notes. This assessed the storage function, the process of reviewing the material, and encoding functions, the process of recording the material, together to determine the effects on student achievement. The results indicated that participants who encoded traditional notes and had time to study performed significantly better than all other participants. Surprisingly, traditional encoders out performed electronic encoders on factual questions and there was no statistical difference on conceptual questions. Results from part three of the study were inconsistent with parts one and two, displaying the necessity for studies in classrooms instead of cognitive learning labs.

An interesting overall analysis of the student generated notes from Oppenheimer and Mueller, (2014) showed a positive correlation between the number of words within a note set and the participants score as well as a negative correlation between the percentage of verbatim notes and the participants score. This may indicate that although encoding more notes is beneficial, it is important to examine the quality of notes as well. Oppenheimer and Mueller concluded that encoding more notes is beneficial, provided the notes are summarized in the participants' own words, which involves the proper implementation and practice of encoding strategies targeting quality notes.

In light of the current literature and the increased implementation of technology in the classroom, the present study was designed to test the effectiveness of the encoding function. Specifically, this study aims to determine actual engagement, perceived engagement, preference and academic achievement of the participants within two modes of note-taking, traditional compared to electronic.

## METHODS AND MATERIALS

### Study Population Demographics

This study took place in fall of 2014, over a period of 20 weeks from August 11-December 19, covering three units, which were taught by the same teacher. All participants included in this study attended Iberville Parish Math, Science, and Arts Academy-West (MSA-W). Of the 101 ninth grade students in the study, 57% were Caucasian students, 43% African American students and 1% were other ethnicities. The gender breakdown of the population was 64% female and 36% male. The majority of the population, 66%, receives free or reduced lunch indicating an overall low socioeconomic status of the study population (Table 1). The participants' in this study were fairly representative of the MSA-W school's population (Table 1).

Table 1. Demographics of Iberville Math, Science, and Arts Academy-West and the study population

|                        | School Population | Electronic Group | Traditional Group | Total Study Population |
|------------------------|-------------------|------------------|-------------------|------------------------|
| <b>Ethnicity</b>       |                   |                  |                   |                        |
| Caucasian              | 55%               | 57%              | 57%               | 57%                    |
| African American       | 42%               | 43%              | 41%               | 43%                    |
| Other                  | 3%                | 0%               | 2%                | 1%                     |
| <b>Gender</b>          |                   |                  |                   |                        |
| Female                 | 53%               | 66%              | 62%               | 64%                    |
| Male                   | 47%               | 34%              | 38%               | 36%                    |
| <b>Economic Status</b> |                   |                  |                   |                        |
| Free/reduced lunch     | 78%               | 61%              | 69%               | 66%                    |
| Full priced            | 22%               | 39%              | 31%               | 33%                    |

### Control versus Experimental Groups

This study compared the effects of traditional note taking versus electronic note taking in a ninth grade biology class. Participants in the study were broken into two groups. Group 1, the control group, completed a note set traditionally. Traditional note taking required the participants to hand write a paper copy of their notes. Group 2, the experimental group, completed the same note set electronically using their school provided laptop (Table 2). Electronic note taking required participants to type their notes creating a digital copy of the material (Table 2). In this study, a note set was composed of teacher given descriptions, pictures, analogies, examples, annotations, questions and/or student comments. Prior to experimentation, students were taught annotation skills. The electronic note takers were given the same activity but also given time to annotate using Microsoft Word. Both groups received instruction and practiced note taking before the study. They were coached on specific tools to assist in effective outlining, prompted to recognize cuing, and facilitate effective summarizing either on paper or electronically.

Table 2. Number of participants in each group, control (traditional note takers) and experimental (electronic note takers) by unit

| Method of note-taking | Unit 1 participants | Unit 2 participants | Unit 3 participants | EOC participants | Survey Participants |
|-----------------------|---------------------|---------------------|---------------------|------------------|---------------------|
| Traditional           | 57                  | 55                  | 53                  | 57               | 54                  |
| Electronic            | 43                  | 36                  | 38                  | 43               | 46                  |

In order to be included in the study, each student had to complete the pretest and the posttest as well as the note set according to his or her test group. Specifically, students were eliminated from the study if they did not take the pre-test within three days of the initial testing date. This ensures that students were not exposed to the content of the unit prior to taking the pre-test. Students were not eliminated if they delayed post-testing, since no additional material on that unit was presented. The criterion to be included in the study applied to each of the three units covered and a participant's data could have been used in one, two, and/or three of the units. For End Of Course (EOC) data to be included participants must have been present for the first and second practice exam as well as the actual EOC issued by the state of Louisiana (Table 2).

### Instruments Measuring Academic Achievement

Table 3 shows a breakdown of the material and assessments given in each of the three units taught as well as a practice End of Course Exam (EOC). Unit one includes scientific method and inquiry, unit two includes cellular functions and cellular transport, unit three includes photosynthesis and cellular respiration, and EOC includes a sample of all Biology content, outlined by the state of Louisiana and its Biology Grade Level Expectations (GLEs). Both treatment groups completed a pretest, participated in class activities, received the opportunity for homework, and completed a posttest for each unit. At the end of the study, every participant completed a student engagement survey.

Table 3. Unit breakdown with assessments used to determine academic achievement

| Unit        | Unit 1                                   | Unit 2    | Unit 3                              | EOC   |
|-------------|--|-----------|-------------------------------------|---|
| Content     | Scientific Inquiry and Scientific Method | Cells     | Photosynthesis and Cell Respiration | All Louisiana 9 <sup>th</sup> grade Biology content |
| Assessments | Pre-test                                 | Pre-test  | Pre-test                            | Pre-test  |
|             | Post-test                                | Post-test | Post-test                           | Mid-year post-test                                  |

Participants were initially assessed using a Biology practice EOC pretest to determine individual prior knowledge of biology content. The Biology practice EOC was composed of 65 multiple-choice questions and was given a second time at the conclusion of the study to determine student growth over one semester. Because Louisiana does not have a complete Biology Practice EOC, Tennessee's Biology End of Course Assessment Practice Test was used to determine initial content knowledge as well as cumulative individual normalized learning gains (NLGs) (Hake, 1998) over one semester. The performance indicators for the Biology curriculum in Tennessee align with Louisiana grade level expectations (Appendix A). Participants were also given an additional pretest at the beginning of each unit. Unit 1 pre/post test, scientific method and inquiry, included 30 multiple-choice questions and five short answer questions (Appendix B). Unit 2 pre/post test, cells and cell transport, included 30 multiple-choice questions and five

short answer questions (Appendix C). Unit 3-pre/post test, photosynthesis and cellular respiration, included 30 multiple-choice questions and five short answer questions (Appendix D). The questions used on each unit test were adapted from Pearson Education, a publishing and assessment company. PearsonSuccessNet aligns assessments specifically to Louisiana Biology GLEs and Louisiana Biology Content Standards to aid in mastery of biology content (Appendix E).

### **Instruments Measuring Student Engagement**

To measure the students' engagement, two different methods were used.

The first method of engagement data collection measured student perceived engagement. An attitudinal survey consisting of 10 engagement questions was administered two months after the final unit post-test (Appendix F) using the online survey data collection software, Survey Monkey. The goals of the survey were to gauge how students felt during the note-taking activity and evaluate their perception of their successes and engagement while taking notes. During semester one, students were assigned note-taking groups. They were required to complete their notes using either a traditional method or an electronic method. During semester two, however, students were allowed to choose their method of note taking. Although no instruments were used to collect data on academic achievement for semester two, students were able to gain exposure and experience with both note-taking methods allowing them to better answer the attitudinal survey.

The second method of measuring student engagement was teacher observed. Students were systematically observed twice during each unit to determine teacher-observed engagement, for a total of six recorded observations during the study. For the purposes of this study, engagement during note taking was determined by three factors:

1. Students were on the correct note-taking slide.
2. Students were only taking notes, not doing any other activity.
3. Students were actively participating or listening during lecture, commonly known as "zoned in" instead of "zoned out."

The teacher walked around the room during notes observing all students and recorded which students were not engaged in the lesson.

### **Analysis of Academic Achievement**

The pretest scores of units 1, 2, 3 and EOC were compared to the posttest scores of each, respectively, to determine normalized learning gains for each student on each assessment (Equation 1)(Hake, 1998). Negative normalized learning gain values were substituted with 0 when pretest scores were greater than posttest scores. Comparisons between the treatment groups were made looking at averages and standard error as well as using an unpaired t test with Welch's correction (Prism 6 for Mac OS X).

Equation 1: Normalized Learning Gain

$$G = \frac{\text{posttest \%} - \text{pretest \%}}{100 - \text{pretest \%}}$$

Data were also collected from subpopulations within the note-taking groups. Two-way analyses of variances (ANOVA) were completed to determine whether there were differences between males versus females, blacks versus whites, and regular economic status versus low economic

status. A linear regression was done to look for trends between normalized learning gains of traditionally high achieving students and traditionally low achieving students. Students categorized in a low economic status were students who received free or reduced priced lunch where regular economic status student paid full price. Students' GPAs at the start of the year were used as an achievement indicator. Specifically, students starting with a GPA of a 3.1 or above were considered traditionally high achieving while students with a 3.0 or below were considered low achieving. No students started the year with less than a 2.0 GPA.

### **Analysis of student engagement**

Student engagement was measured two ways. The first method was self-reported by the students. These survey responses were analyzed two ways for each note-taking group, including chi-square tests and a binominal test. For the binomial test, only student responses that exhibited a strong preference for either traditional or electronic note taking were considered. The total engagement on the survey was calculated by averaging the student's off task behavior per class. This was analyzed by an unpaired t test with Welch's correction. The second method measuring student engagement was teacher observation. Teacher observed engagement was analyzed by summing off-task behavior during six observations. Off task behavior was analyzed using an unpaired t test, also with Welch's correction, and a linear regression.

### **Institutional Review Board Approval**

This project was approved by the Louisiana State University Institutional Review Board, exemption #E8824 (Appendix G), and Iberville Parish Schools. The students voluntarily participated in this study and provided a signed student assent form and a signed parental consent form.

## RESULTS

### Traditional and Electronic Initial Comparison

Of the 103 students who participated in this study, 57 made up the traditional note-taking group and 46 made up the electronic note-taking group. The Integrated Louisiana Educational Assessment Program (iLEAP) data from students' 7<sup>th</sup> grade year and the Louisiana Educational Assessment Program (LEAP) data from their 8<sup>th</sup> grade year were gathered prior to experimentation. The iLEAP and LEAP assessments are standard-based assessments where items are based on grade specific Louisiana academic content standards. Data from each of these tests were analyzed using an unpaired t test with Welch's correction, assuming unequal standard deviations to determine if any differences existed within the test populations. There were no significant differences between treatment groups on the iLEAP test ( $p=0.9739$ ). Students in the traditional note-taking group averaged  $325.5 \pm 5.292$ ,  $n=50$  and students in the electronic note-taking group averaged  $325.3 \pm 4.491$ ,  $n=41$ , with no significant difference between the two. There were also no significant differences in student scores on the LEAP test ( $p=0.4940$ ). Students in the traditional note-taking group averaged  $335.0 \pm 4.415$ ,  $n=51$ , while electronic note-takers averaged  $330.2 \pm 5.436$ ,  $n=43$ , also with no significant difference between the note-taking groups.

When the average scores for subpopulation were compared, there were no significant differences. The average scores between each subpopulation of gender, race, socioeconomic status, or GPA were not significantly different on iLEAP and LEAP (Table 4).

Table 4. Average Integrated Louisiana Educational Assessment Program (iLEAP) and Louisiana Educational Assessment Program (LEAP) scores for traditional and electronic note-taking groups broken down by subpopulations.

|                      | Traditional Group |       | Electronic Group |       |
|----------------------|-------------------|-------|------------------|-------|
|                      | iLEAP             | LEAP  | iLEAP            | LEAP  |
| Gender               |                   |       |                  |       |
| Male                 | 332.1             | 337.4 | 322.2            | 327.6 |
| Female               | 321.1             | 333.5 | 331.2            | 335.1 |
| Race                 |                   |       |                  |       |
| White                | 331.6             | 340.5 | 325.3            | 331.8 |
| Black                | 317.7             | 328.3 | 325.3            | 328.2 |
| Socioeconomic status |                   |       |                  |       |
| Below average        | 318.7             | 327.3 | 323.2            | 331.2 |
| Average              | 338.8             | 350.8 | 328.6            | 328.7 |
| GPA                  |                   |       |                  |       |
| Above 3.0            | 330.8             | 341.3 | 333.0            | 344.4 |
| 3.0 and below        | 315.4             | 321.9 | 315.1            | 316.0 |

### Traditional and Electronic Note-Taking Comparison

Normalized Learning Gains (NLGs) were calculated from pre and post-test data for Unit 1, Unit 2, Unit 3 and a Practice EOC (Equation 1). NLGs with negative values were changed to 0, assuming knowledge between pre and post-tests cannot be lost. These data were analyzed

using unpaired t tests with Welch's correction, assuming unequal standard deviations. The average NLGs for traditional and electronic note-takers was not significantly different for any unit tested (Unit 1:  $p=0.2299$ , Unit 2:  $p=0.5055$ , Unit 3:  $p=0.8208$ , Practice EOC:  $p=0.1953$ ) (Figure 2).

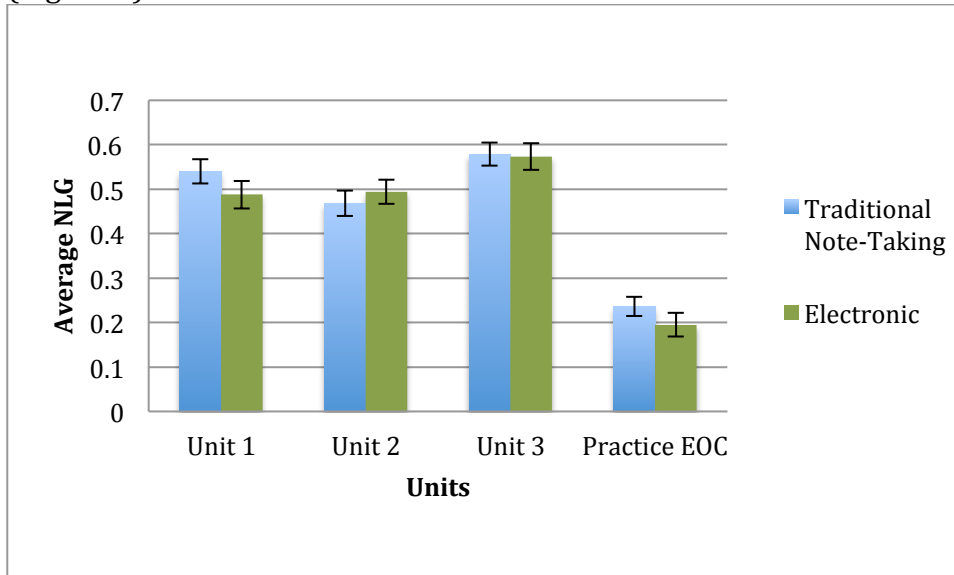


Figure 3: Average normalized learning gains (NLG)  $\pm$  standard error for traditional and electronic note takers respectively for Units 1 ( $n=57,43$ ), Unit 2 ( $n=55,36$ ), Unit 3 ( $n=53,38$ ), and Practice End of Course examination (EOC) ( $n=57,43$ ). There were no differences between the traditional and electronic note-taking groups.

Because there was no difference in learning gains between the traditional and electronic note taking groups, subpopulations were assessed to determine if the method of note taking affected normalized learning gains of students within those subgroups.

## Gender

Students were also separated by gender within their note-taking groups. An ANOVA showed differences between normalized learning gains for each unit assessed (Figure 4). Unit 1 showed a statistical significance between NLG of the treatment groups ( $p=0.04$ ) and some significant interaction between gender and the type of note taking ( $p=0.04$ ). Specifically, electronic note taking reduced the normalized learning gains in males, but increased the normalized learning gains of females. Unit 1 data showed electronic note-taking females, who averaged a NLG of  $+0.52$ , exhibited greater gains than their male counterparts, whose NLG averaged  $+0.40$  (Figure 4). The opposite was true for the traditional note-takers where males averaged a NLG of  $+0.58$  compared to their female counterparts whose NLG was  $+0.52$  (Figure 4). In Unit 2, however, there were no statistical differences or interactions.

In Unit 3, there were no differences between gender and treatment, however there was some significant interaction between them ( $p=0.03$ ). Specifically, electronic note taking reduced the normalized learning gains in males, but increased the normalized learning gains of females. Unit 3 data showed electronic note-taking females, who averaged a NLG of  $+0.61$ , exhibited greater gains than their male counterparts, whose NLG averaged  $+0.49$  (Figure 4). The opposite was true for the traditional note-takers where males averaged a NLG of  $+0.62$  compared to their female counterparts whose NLG was  $+0.56$  (Figure 4). This is consistent with Unit 1 results.

When examining gender and NLG from Practice EOC, significant interactions ( $p=0.02$ ) were evident, however these interactions were different from those interactions observed in Unit 1 and Unit 3. On the practice EOC, electronic note taking increased the normalized learning gains in males, but decreased the normalized learning gains of females. EOC data showed electronic note-taking males had an average NLG of +0.28, which was greater than the average NLG of electronic note-taking females, which was only +0.17.

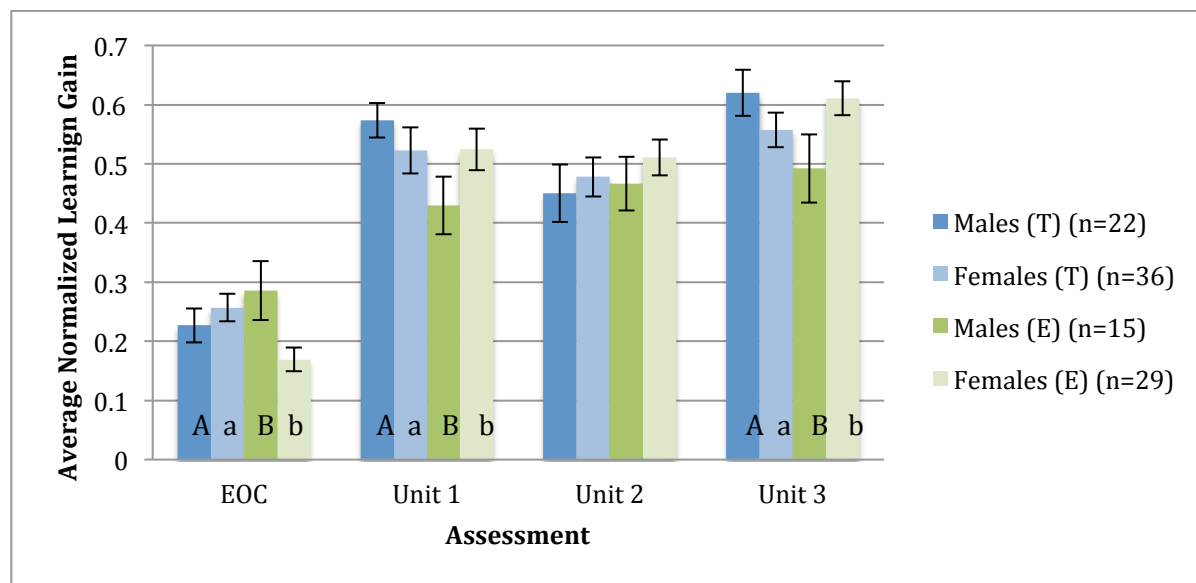


Figure 4. Average normalized learning gains (NLG)  $\pm$  standard error for males and females for traditional (T) and electronic note (E) takers respectively for Unit 1, Unit 2, Unit 3, and Practice End of Course examination (EOC). Series “A” or “a” is significantly different than series “B” or “b.”

### Race

Note-taking groups were also separated by race. An ANOVA was used to compare black students to white students, indicating there were no significant interactions between students’ normalized learning gains of a particular race within respective note-taking groups for any of the units tested (EOC:  $p=0.9962$ , Unit 1:  $p=0.9596$ , Unit 2:  $p=0.2128$ , Unit 3:  $p=0.3461$ ) (Figure 5).

### Economic Status

The impact of economic status on normalized learning gains of students within the two note-taking groups was analyzed. Economic status was determined by the students’ lunch status. Those students who paid regular price for lunch were considered regular economic status and those students who received free or reduced lunch rates were considered low economic status. An ANOVA indicated no statistical differences in the interactions between NLG averages between the economic status and the note-taking method of these groups for each unit (EOC:  $p=0.8761$ , Unit 1:  $p=0.5476$ , Unit 2:  $p=0.1261$ , Unit 3:  $p=0.3473$ ) (Figure 6).



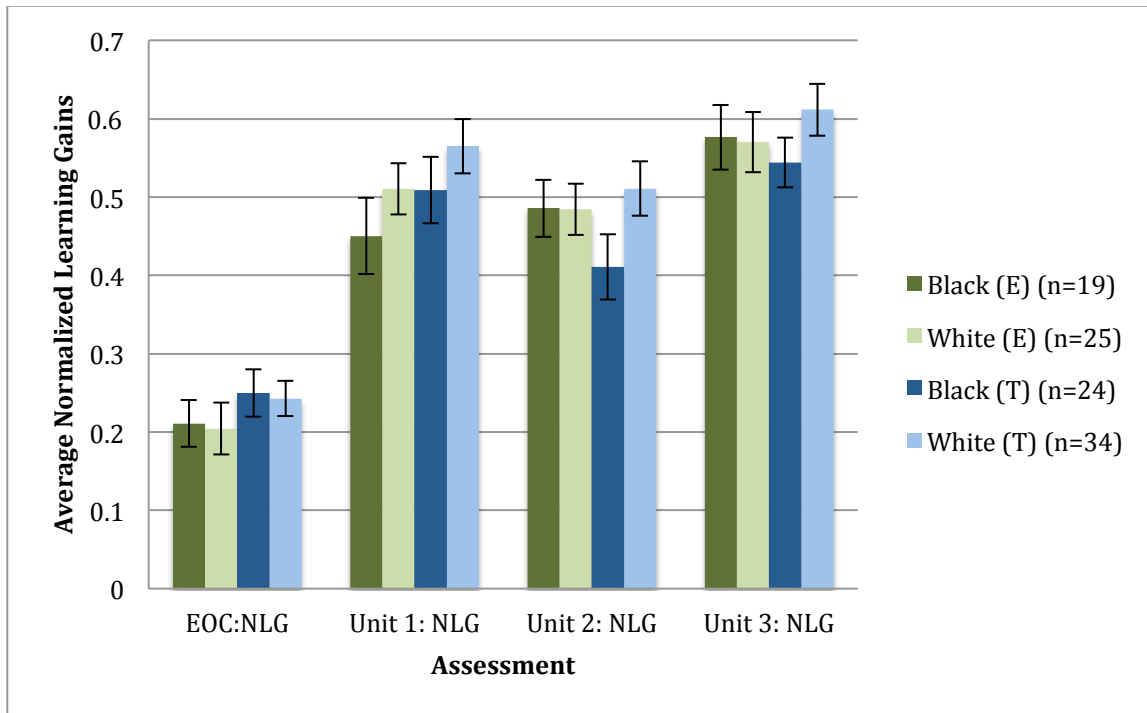


Figure 5. Average normalized learning gains (NLG)  $\pm$  standard error for black and white students from the traditional (T) and electronic (E) note taking groups respectively for Unit 1, Unit 2, Unit 3, and Practice End of Course examination (EOC).

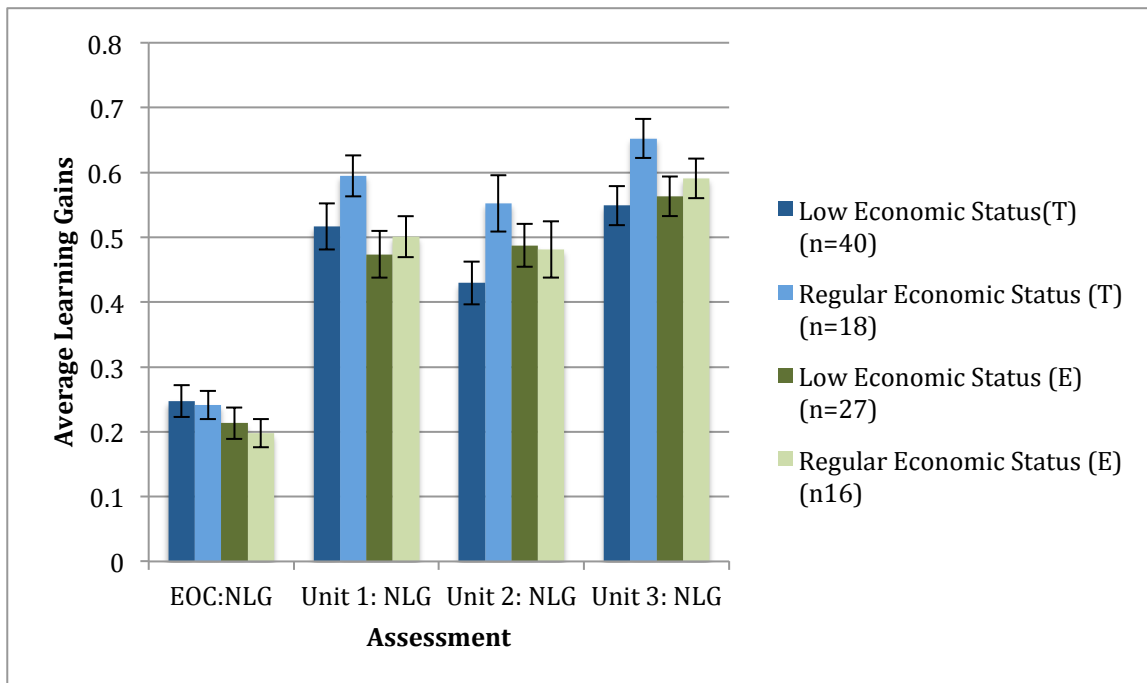


Figure 6. Average normalized learning gains (NLG)  $\pm$  standard error for students categorized by economic status for traditional (T) and electronic (E) note-takers respectively for Unit 1 Unit 2, Unit 3, and Practice End of Course examination (EOC).

## GPA

Students within note-taking groups were separated into subgroups based on their starting grade point averages. Students starting the year with high GPAs, 3.1 or above were compared to students starting the year with low GPAs, 3.0 and below. There were differences between these two groups, which was expected. However, when comparing high GPA students from both note-taking groups, there were no differences in average normalized learning gains (ANOVA,  $p=0.53$ ). Similar results were found when low GPA students from both treatment groups were compared and no differences were found (ANOVA,  $p=0.17$ ).

Traditional note takers who had a GPA of 3.1 or above at the beginning of the year displayed a positive correlation between GPA and the sum of NLG for three units (Linear regression,  $p=0.003$ ,  $y = 0.8887x - 1.367$ ,  $R^2 = 0.3341$ ), however there was no correlation in high achieving students who took notes electronically (Linear regression,  $p=0.10$ ,  $y = 0.4492x + 0.1770$ ,  $R^2 = 0.3129$ ). The slope of the high GPA traditional group was not significantly different than the slope of the high GPA electronic group ( $p=0.27$ ), indicating that although a positive correlation exists in the traditional group, it is very weak (Figure 7).

These trends shown for high GPA students were not present for students in the low group, who had a GPA of 3.0 or less. There were no differences in slope between traditional and electronic note takers (linear regression,  $p=0.35$ ). There were also no correlations in traditional note takers (linear regression,  $p=0.07$ ,  $y = 1.035x - 1.438$ ,  $R^2 = 0.1859$ ) or in electronic note takers (linear regression,  $p=0.14$ ,  $y = 0.5446x + 0.0054$ ,  $R^2 = 0.1512$ ) between GPA and the sum of NLG from three units (Figure 8).

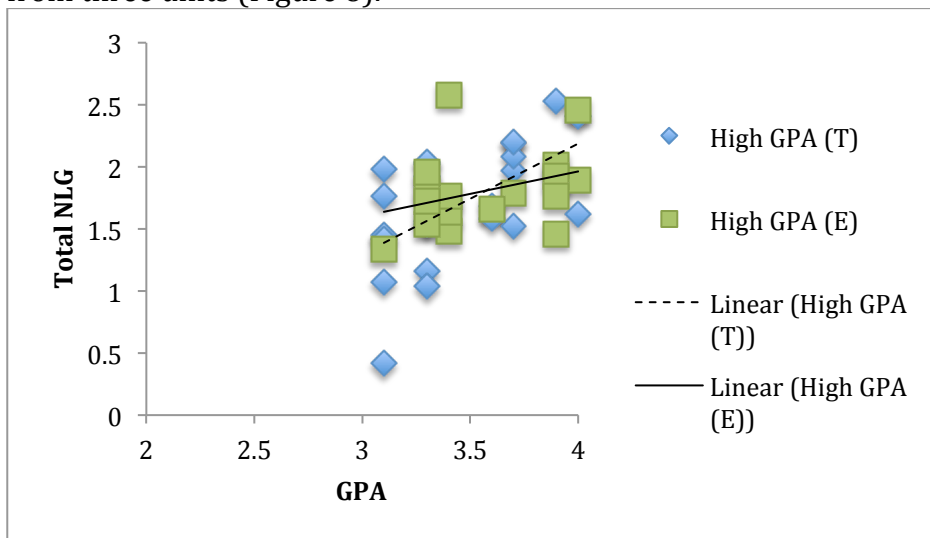


Figure 7: Correlation between High GPAs and the sum of normalized learning gains from Units 1, 2, and 3 for traditional (T) ( $y = 0.8887x - 1.367$ ,  $R^2 = 0.3341$ ) ( $n=33$ ) and electronic (E) ( $y = 0.4492x + 0.1770$ ,  $R^2 = 0.3129$ ) ( $n=20$ ) note takers.

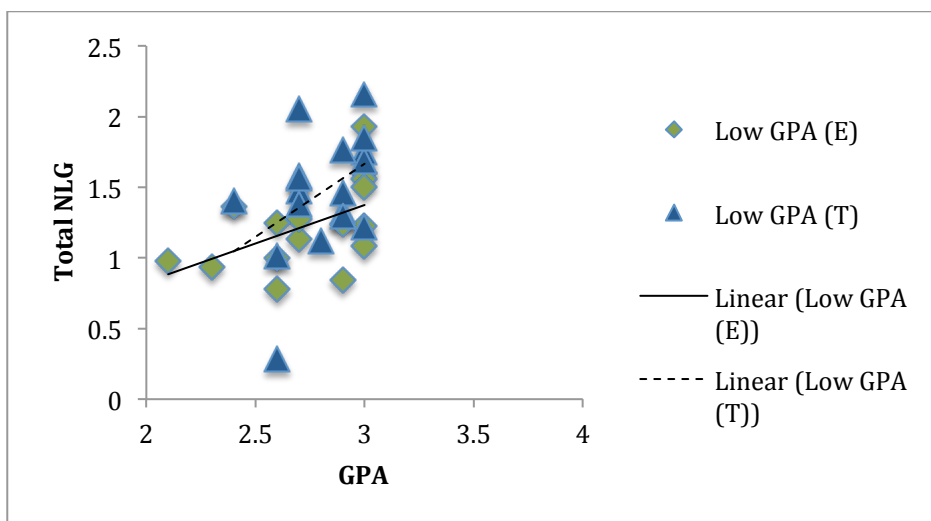


Figure 8. Correlation between Low GPAs and the sum of normalized learning gains (NLG) from Units 1, 2, and 3 for traditional (T)( $y = 1.035x - 1.438$ ,  $R^2 = 0.1859$ ) ( $n=15$ ) and electronic (E) ( $y = 0.5446x + 0.0054$ ,  $R^2 = 0.1512$ ) ( $n=22$ ) note takers.

### Student-Perceived Engagement and Preference

Of 100 students surveyed from both groups of note takers, sixty-four percent of students perceive traditional note taking takes longer than electronic note taking (Table 5). However, 45% of students perceive the traditional note taking method to be easier and 52% feel they learn the most with this method. When self-reporting, 56% of students said they are most distracted when taking electronic notes and 51% prefer traditional note taking (Table 5).

The method of note taking during this study did not change the engagement or preferences of the student (Table 5). Both traditional and electronic note takers completed the survey with no significant differences in their responses. Students who used the traditional note-taking method, as well as students who used the electronic note-taking method, thought the traditional note-taking method was easier. Both groups also agree that traditional note taking is more time consuming, however they feel they are less distracted and they learn more when using the traditional note-taking method. Overall, the survey data shows that students prefer traditional note taking, they believe they learn the most from traditional note taking, and they perceive their grades are better when taking notes using a traditional method.

The average number of times each group of students were not engaged in note taking for each class period differed between the traditional and electronic note takers (unpaired t test with Welch's correction,  $p=0.04$ ) (Table 5). The traditional note takers report they are likely to be distracted an average of 7.72 times per class and electronic note takers report a higher average of 8.74 distractions per class (Table 5). A binomial test was also conducted to determine differences in the note-taking preference of the students. Of those who exhibited a strong preference for either traditional or electronic note taking, 51 students, or 63%, preferred traditional and 30 students, or 37%, preferred electronic. If no bias existed, the preference ratio should be 50/50, however this was not the case. Twenty-six percent more students preferred taking note traditionally than electronically ( $p=0.01$ ) (Table 5), indicating a clear preference of traditional note taking.

Table 5. Attitudinal survey comparing preferences of traditional note takers, electronic note takers, and traditional and electronic note takers combined, indicating an overall preference for traditional note taking, which are highlighted in green.

|   | Electronic notes (%) | Traditional notes (%) | Both, Neither or Not Sure (%) |
|---|----------------------|-----------------------|-------------------------------|
| I feel note taking is easiest when using...       |                      |                       |                               |
| Traditional note takers                           | 28                   | 48                    | 24                            |
| Electronic note takers                            | 26                   | 41                    | 32                            |
| Total   | 27                   | 45                    | 28                            |
| I feel like note taking takes the longest when... |                      |                       |                               |
| Traditional note takers                           | 19                   | 70                    | 9                             |
| Electronic note takers                            | 33                   | 57                    | 11                            |
| Total   | 25                   | 64                    | 11                            |
| I feel like I learn the most when...              |                      |                       |                               |
| Traditional note takers                           | 17                   | 57                    | 25                            |
| Electronic note takers                            | 24                   | 46                    | 21                            |
| Total   | 20                   | 52                    | 28                            |
| I prefer...                                       |                      |                       |                               |
| Traditional note takers                           | 30                   | 58                    | 13                            |
| Electronic note takers                            | 31                   | 44                    | 24                            |
| Total   | 30                   | 51                    | 18                            |
| I learn more from...                              |                      |                       |                               |
| Traditional note takers                           | 20                   | 56                    | 25                            |
| Electronic note takers                            | 27                   | 50                    | 24                            |
| Total   | 23                   | 53                    | 24                            |
| I am most distracted when...                      |                      |                       |                               |
| Traditional note takers                           | 57                   | 11                    | 26                            |
| Electronic note takers                            | 54                   | 15                    | 29                            |
| Total   | 56                   | 13                    | 31                            |
| My grades are better when I use...                |                      |                       |                               |
| Traditional note takers                           | 17                   | 56                    | 28                            |
| Electronic note takers                            | 22                   | 41                    | 37                            |
| Total   | 19                   | 49                    | 32                            |

Table 6. Survey data of traditional and electronic note takers perceived engagement during one class period, indicating traditional note takers average less total distractions than electronic note-takers (unpaired t test with Welch's correction,  $p=0.04$ ).

|                        | On a different webpage | Doing something that isn't notes | "Zoned out"     | Total Distractions |
|------------------------|------------------------|----------------------------------|-----------------|--------------------|
| Traditional Note-Taker | $1.63 \pm 2.59$        | $2.17 \pm 2.50$                  | $3.92 \pm 3.50$ | $7.72 \pm 3.11$    |
| Electronic Note Taker  | $2.23 \pm 3.57$        | $2.67 \pm 3.43$                  | $3.84 \pm 4.09$ | $8.74 \pm 3.761^*$ |

### Teacher-Observed Student Engagement

During the course of the study, six lessons were observed by the teacher to determine how often students lacked engagement in the note taking process. The sum from all six observations of off task instances typically ranged from 0 to 8, with one student being off task 17 times. This student was eliminated from the analysis. There were no differences between teacher-observed engagement in the traditional note taking group and electronic note taking group (unpaired t-test with Welch's correction,  $p=0.25$ ) (Table 7). The correlation between teacher-observed disengagement and sum of NLG was also analyzed. The electronic note-taking group experienced a greater range of NLG from the average, however the NLGs between both note-taking groups were not different (Figure 9). There was no correlation between the sum of NLG and teacher observed student engagement for the traditional group (linear regression,  $p=0.39$ ,  $y = -0.0387x + 1.651$ ,  $R^2 = 0.01564$ ), however there was a negative correlation in the electronic note-taking group (linear regression,  $p=0.01$ ,  $y = -0.1043x + 1.731$ ,  $R^2 = 0.1995$ ). This indicates the more the electronic note taker is off task, the lower the normalized learning gains will be. However, a comparison of the slopes from each note-taking group shows no difference between the two ( $p=0.27$ ) indicating only weak correlations in the electronic group (Figure 9).

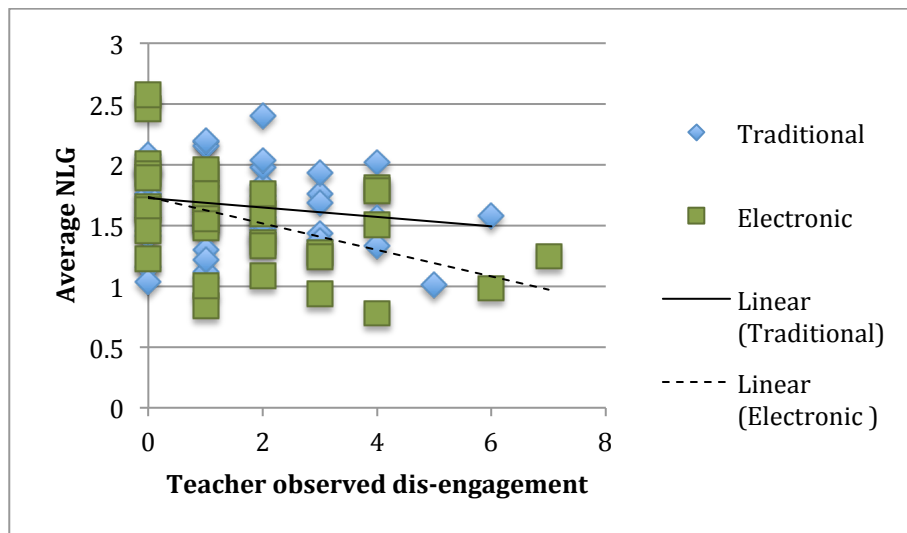


Figure 9. Comparison of teacher observed engagements and average normalized learning gains (NLG) from Units 1, 2, and 3 combined for traditional and electronic treatment groups.

Traditional group:  $y = -0.0387x + 1.651$ ,  $R^2 = 0.01564$  (n=58); Electronic group:  $y = -0.1043x + 1.731$ ,  $R^2 = 0.1995$  (n=44).

### Teacher Observed versus Student Perceived Engagement

Teacher observed and student perceived dis-engagement are reported in Table 7. Data for teacher observed engagement was determined by summing the number of times a student was off task during six classroom observations. Data for student perceived engagement was taken from a survey asking students the average number of times they were off task in one class period. Table 7 shows the teacher observed 1.47 and 1.89 instances of off task behavior for the traditional and electronic group respectively, however students reported they were off task 7.72 instances for the traditional group and 8.74 instances for the electronic group. Students perceived lack of engagement much more frequently than the teacher, especially since the teacher observed data is over 6 classes while student perceived data is only over one class period. There is a dramatic increase in the average number of times per class a student reports participating in some activity that was not the assigned note set, possibly indicating students are more aware of off task behavior.

Table 7: Comparison of teacher observed dis-engagement to student perceived dis-engagement. Data for teacher observed engagement was determined by summing the number of times a student was off task during six classroom observations  $\pm$  standard error while data for student perceived engagement was taken from a survey asking students the average number of times they were off task in one class period  $\pm$  standard error. Differences existed only in student perceived engagement data.

|             | Teacher Observed | Student Perceived |
|-------------|------------------|-------------------|
| Traditional | 1.47 $\pm$ 2.51  | 7.72 $\pm$ 3.11   |
| Electronic  | 1.89 $\pm$ 1.94  | 8.74 $\pm$ 3.76*  |

## DISCUSSION

This study looked at the potential impacts of note-taking method on three different student focused components, student performance, student engagement and student preference. There were no initial differences in academic performance between the two treatment groups (Table 4). After taking notes using either a traditional method or an electronic method, normalized learning gains were measured and it was determined that the method of note taking did not affect the academic achievement of 9<sup>th</sup> graders in Biology. Students who took notes using an electronic method performed equally as well as students who took notes using a traditional method (Figure 3). Most subpopulations studied also showed no significant differences in academic performance between traditional and electronic note takers. Specifically, no differences existed between the study population of blacks and whites (Figure 5), low economic status and regular economic status (Figure 6) or typically high achieving (Figure 7) and typically low achieving students (Figure 8) on any units.

Inconsistent results between different units for males and females were evident (Figure 4). In the Unit 3 data electronic females exhibited greater gains than their male counterparts. The opposite was true for the traditional note-takers with males exhibiting greater learning gains compared to their female counterparts. The EOC data resulted in electronic note-taking males having greater NLG than electronic note-taking females. Some research suggests a possible gender bias towards students with higher pre-test scores, typically males, resulting in overall higher normalized learning gains of that gender (Willoughby and Metz, 2009). If this were the case, we would have seen consistently higher gains in the male population. Since this was not observed, any differences in NLG was most likely due to other driving factors besides gender. Possible influences could be variation in content between units or differences in students' prior experiences. Methods of calculating learning gains and how it impacts bias towards gender should be more carefully considered in future studies. Overall, the findings from subpopulation analysis may support the idea that regardless of classroom demographics, students using an electronic note taking method will perform just as well as students using a traditional note taking method.

One major concern expressed by many teachers is that students using electronic note-taking methods will be more easily distracted due to the ease with which the technology can be used for other purposes. Student engagement during traditional and electronic note taking was significantly different ( $p=0.0379$ ) when engagement was self-reported by the students (Table 7), however, not significantly different when observed by the teacher ( $p=0.2462$ ) (Figure 7). This is most likely because teacher observed engagement was less effective at catching off task behavior. Since this study took place in a classroom on a daily basis, students were most likely afraid to be caught off task. Traditionally, off task behavior results in reprimanding, subsequently triggering students to hide off task behavior by quickly changing screens when the teacher walks by. This is the most likely reason student self reported engagement data does not align with teacher observed engagement data. Despite this, I feel comfortable saying students who took notes electronically were off task more often than students who took notes traditionally.

In addition, there were no differences in the normalized learning gains between each note taking group indicating engagement was not a driving factor in student achievement for this

study. Current literature is split regarding the use of technology in the classroom and its effects on student engagement. Some studies suggest that the use of computers increases student engagement (Suhr et al., 2010; Bebell and Kay, 2010; Dwyer, 1994; Driver, 2002) however the results of this study are more aligned with more recent literature that suggest computer use during class decreases student engagement (Sana et al., 2013; Aagaard, 2015; Taneja et al., 2015; Oppenheimer and Mueller, 2014; Wood et al, 2012; Awwad et al., 2013). A possible limitation of using the electronic note taking method could be that the process of taking notes alone does not lend itself to increasing student engagement. This may be because within the encoding function there is ease in the ability to transcribe verbatim what the teacher says. It may be more difficult for students in the electronic group to organize, reword, condense or synthesize lectured information compared to those in the well-practiced traditional note-taking group. If this is the case, then it may make sense that students are less engaged because they are thinking less during the note taking process.

Lastly, this study addressed student preference. Across both note-taking groups, significantly more students preferred taking notes using a traditional note taking method rather than an electronic note taking method. The results also suggest that both groups found traditional note taking easier, even though both groups felt that traditional note taking takes longer. While these results are not due to the students' unfamiliarity with laptops, this particular group of students has had personal laptops for three full academic years before starting this study. Many may lack the experience necessary to take notes electronically. On average, the study participants took notes two or three times a week, for less than an hour each time, over the course of the 20-week study. This intervention may not have been enough to overcome years of academic exposure to traditional note taking. Therefore, the students' experiences prior to this study could be a main factor in their note taking preference.

When dealing with the implementation of technologies in classrooms, it is important to consider all impacts. Dealing with technologies is neither a question of uncritical acceptance nor blind resistance but rather somewhere between yes and no we are looking for a how (Verbeek, 2013). Based on this study, since there is no clear consensus on the impacts of using computers on achievement, perhaps allowing students to choose their own method of note taking could at least provide a means to enhance class culture and empower the students to be involved in their learning. The use of technology in class may lead to students being distracted and choosing to multitask during lecture or it may lead to increased engagement and positive feelings towards science, ultimately it is up to the teacher to create a climate as well as culture conducive to increasing student performance. Classroom climate is viewed as behavior, while classroom culture is comprised on values and norms (Macneil et al., 2009). To change what students are doing during class teachers must get the students to change what is important to them. Having the option to take notes using a traditional or an electronic method allows flexibility for different learning styles, a means for differentiating instruction, and allows students to feel that their opinion matters, ultimately creating a class culture that promotes the possibility to increase student performance (Macneil et al., 2009).

An educator's ultimate goal is to prepare students for the future. Often this can be accomplished through increasing student performance on standardized test, leading to acceptance to accredited colleges and universities. However a recent shift in college readiness now includes the ability to integrate technology into the cognitive learning process, specifically using



computers as a note-taking tool. Traditional note taking, specifically the encoding function (DiVesta and Gray, 1972), which is the process of recording lecture material, has been an important metacognitive tool for over 90 years (Crawford, 1925; Fisher and Harris, 1974; Hartley and Davies, 1978; and Kiewra, 1985; Marzano et al., 2001) leading to increases in student achievement. One way to boost student achievement is to enhance the encoding function by improving the quantity and quality of notes. Early research suggest that improving the encoding process can be done by cueing students to which notes should be recorded (Moore, 1968), writing the essential concepts on the board (Locke 1977), providing note taking strategies and feedback (Robin et al., 1977), and repeating the lecture material (Kiewra et al., 1989). Since this study did not find any significant impacts of electronic note taking on student achievement, perhaps a different method of electronic encoding than the one used in this study should be adapted. Like all things, to be good at something, one needs practice. Students need much more practice taking efficient notes, specifically efficient electronic notes. Teachers should implement repetition, cuing, and the identification of essential information during the electronic note taking process. More study is obviously needed to address the associations between specific electronic note taking strategies and note-quality.

Recent studies show that student achievement and engagement can be improved by the proper implementation of technology into the classroom, specifically through the use of computers (Penuel, 2006; Wenglinsky, 1998; Bartsch and Cobern, 2003; Lei and Zhao, 2007). Hundreds of students and teachers participated in the Apple Classroom of Tomorrow Initiative, implementing a 1:1 ratio of computers to students across the country. That study concluded an increased potential for learning and engagement when students were equipped with computers in the classroom. Computers can facilitate the electronic note taking process by increasing the number of words recorded; students who took more notes performed better (Oppenheimer and Mueller, 2014). However, computers used for note taking also increase the number of verbatim words written; students whose notes had more verbatim overlap with the lecture did not perform as well as students who had less verbatim notes (Oppenheimer and Mueller, 2014). This study did not address note quality or quantity. Future studies could address these factors to try to improve electronic note taking. When in a 1:1 school, perhaps administrators and teachers could work together to adapt traditional note taking methods to better fit the digital age, specifically addressing note quantity and quality. Ultimately electronic note taking could be integrated across all grade levels and all content disciplines.

Is there a specific note-taking strategy that is more effective for computer notes? Does this specific strategy impact academic performance more than traditional note taking? These questions are significant because, as stated earlier, note taking is a critical skill that becomes a primary means of learning in most academic settings (Crawford, 1925; Fisher and Harris, 1974; Hartley and Davies, 1978; and Kiewra, 1985; Marzano et al., 2001), and the integration of technology into classroom has become increasingly popular (Penuel, 2006; Wenglinsky, 1998; Bartsch and Cobern, 2003; Lei and Zhao, 2007). Therefore, how can the process of electronic note taking be seamlessly integrated into the classroom climate? The answer to these questions requires further study and has the potential to significantly alter student achievement in classrooms across the country.

**Next Steps**

This study is limited in that the sample is small for both the traditional note-taking group (n=58) and the electronic note-taking group (n=44). In addition, this study shows only 9<sup>th</sup> grade students at an overall high performing public school. Students' prior experiences could have played a large part in the note taking preferences since the participants had limited practice note taking using computers. A larger sample or a study across multiple schools may strengthen the findings of this study. In addition, note taking methods specific to electronic notes should be explored to determine any possible changes in engagement or achievement. Since increasing note quality in traditional note taking seems to increase academic achievement, future studies could also look for significant differences in the quality of student-generated notes in the hopes of finding ways to increase electronic note quality and ultimately increase achievement.

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## APPENDIX A: LA/TN ALIGNMENT

Louisiana Grade Level Expectations aligned with Tennessee Course Level Expectations showing standards from Tennessee practice EOC fit the Louisiana course for Biology

| <b>Louisiana GLEs</b>  | <b>Tennessee CLEs</b>   |
|--|---|
| 1. Write a testable question or hypothesis when given a topic (SI-H-A1)  | CLE 3210.Inq.2<br>Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.   |
| 2. Describe how investigations can be observation, description, literature survey, classification, or experimentation (SI-H-A2)  | CLE 3210.Inq.1<br>Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.   |
| 3. Plan and record step-by-step procedures for a valid investigation, select equipment and materials, and identify variables and controls (SI-H-A2)  | CLE 3210.Inq.2<br>Design and conduct scientific investigations to explore new phenomena, verify previous results, test how well a theory predicts, and compare opposing theories.   |
| 4. Conduct an investigation that includes multiple trials and record, organize, and display data appropriately (SI-H-A2)   | CLE 3210.Inq.4<br>Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.   |
| 5. Utilize mathematics, organizational tools, and graphing skills to solve problems (SI-H-A3)  | CLE 3210.Inq.4<br>Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.<br>CLE 3210.Math.1<br>Understand the mathematical principles associated with the science of biology.<br>CLE 3210.Math.2<br>Utilize appropriate mathematical equations and processes to understand biological concepts |
| 6. Use technology when appropriate to enhance laboratory investigations and presentations of findings (SI-H-A3)  | CLE 3210.Inq.3<br>Use appropriate tools and technology to collect precise and accurate data.<br>CLE 3210.T/E.1<br>Explore the impact of technology on social, political, and economic systems.  |
| 7. Choose appropriate models to explain scientific knowledge or experimental results (e.g., objects, mathematical relationships, plans, schemes, examples, role-playing, computer simulations) (SI-H-A4) | CLE 3210.Math.1<br>Understand the mathematical principles associated with the science of biology.<br>CLE 3210.Math.2<br>Utilize appropriate mathematical equations  |

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|  | and processes to understand biological concepts   |
| 8. Give an example of how new scientific data can cause an existing scientific explanation to be supported, revised, or rejected (SI-H-A5)   | CLE 3210.Inq.5<br>Compare experimental evidence and conclusions with those drawn by others about the same testable question.  |
| 9. Write and defend a conclusion based on logical analysis of experimental data (SI-H-A6) (SI-H-A2)  | CLE 3210.Inq.4<br>Apply qualitative and quantitative measures to analyze data and draw conclusions that are free of bias.<br>CLE 3210.Inq.6<br>Communicate and defend scientific findings.    |
| 10. Given a description of an experiment, identify appropriate safety measures (SI-H-A7)   | CLE 3210.T/E.4<br>Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.   |
| 11. Evaluate selected theories based on supporting scientific evidence (SI-H-B1)   | CLE 3210.Inq.5<br>Compare experimental evidence and conclusions with those drawn by others about the same testable question.  |
| 12. Cite evidence that scientific investigations are conducted for many different reasons (SI-H-B2)  | CLE 3210.T/E.2<br>Differentiate among elements of the engineering design cycle: design constraints, model building, testing, evaluating, modifying, and retesting,                            |
| 13. Identify scientific evidence that has caused modifications in previously accepted theories (SI-H-B2)   | CLE 3210.Inq.1<br>Recognize that science is a progressive endeavor that reevaluates and extends what is already accepted.   |
| 14. Cite examples of scientific advances and emerging technologies and how they affect society (e.g., MRI, DNA in forensics) (SI-H-B3)   | CLE 3210.T/E.4<br>Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems.   |
| 15. Analyze the conclusion from an investigation by using data to determine its validity (SI-H-B4)<br>16. Use the following rules of evidence to examine experimental results:<br>(a) Can an expert's technique or theory be tested, has it been tested, or is it simply a subjective, conclusive approach that cannot be reasonably assessed for reliability?<br>(b) Has the technique or theory been subjected to peer review and publication?<br>(c) What is the known or potential rate of | CLE 3210.Inq.5<br>Compare experimental evidence and conclusions with those drawn by others about the same testable question.<br>CLE 3210.Inq.6<br>Communicate and defend scientific findings. |



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| <p>error of the technique or theory when applied?</p> <p>(d) Were standards and controls applied and maintained?</p> <p>(e) Has the technique or theory been generally accepted in the scientific community? (SI-H-B5) (SI-H-B1) (SI-H-B4)</p> |   |
| 1. Compare prokaryotic and eukaryotic cells (LS-H-A1)  | <p>CLE 3210.1.1</p> <p>Compare the structure and function of cellular organelles in both prokaryotic and eukaryotic cells.</p>  |
| 2. Identify and describe structural and functional differences among organelles (LS-H-A1)  | <p>CLE 3210.1.1</p> <p>Compare the structure and function of cellular organelles in both prokaryotic and eukaryotic cells.</p> <p>CLE 3210.1.2</p> <p>Distinguish among the structure and function of the four major organic macromolecules found in living things.</p> |
| 3. Investigate and describe the role of enzymes in the function of a cell (LS-H-A1)  | <p>CLE 3210.1.2</p> <p>Distinguish among the structure and function of the four major organic macromolecules found in living things.</p> <p>CLE 3210.1.3</p> <p>Describe how enzymes regulate chemical reactions in the body.</p>                                       |
| 4. Compare active and passive cellular transport (LS-H-A2)   | <p>CLE 3210.1.5</p> <p>Compare different models to explain the movement of materials into and out of cells.</p>   |
| 5. Analyze the movement of water across a cell membrane in hypotonic, isotonic, and hypertonic solutions (LS-H-A2)   | <p>CLE 3210.1.5</p> <p>Compare different models to explain the movement of materials into and out of cells.</p>   |
| 6. Analyze a diagram of a developing zygote to determine when cell differentiation occurs (LS-H-A3)  | <p>CLE 3210.1.4</p> <p>Describe the processes of cell growth and reproduction.</p>  |
|  | <p>CLE 3210.1.2</p> <p>Distinguish among the structure and function of the four major organic macromolecules found in living things.</p>  |
| 7. Identify the basic structure and function of nucleic acids (e.g., DNA, RNA) (LS-H-B1)   | <p>CLE 3210.4.1</p> <p>Investigate how genetic information is encoded in nucleic acids.</p> <p>CLE 3210.1.2</p> <p>Distinguish among the structure and function of the four major organic macromolecules found in living things.</p>                                    |

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| 8. Describe the relationship among DNA, genes, chromosomes, and proteins (LS-H-B1)   | CLE 3210.4.2<br>Describe the relationships among genes, chromosomes, proteins, and hereditary traits.   |
| 9. Compare mitosis and meiosis (LS-H-B2)   | CLE 3210.4.5<br>Recognize how meiosis and sexual reproduction contribute to genetic variation in a population.  |
| 10. Analyze pedigrees to identify patterns of inheritance for common genetic disorders (LS-H-B3)   | CLE 3210.4.6<br>Describe the connection between mutations and human genetic disorders.  |
| 11. Calculate the probability of genotypes and phenotypes of offspring given the parental genotypes (LS-H-B3)                                  | CLE 3210.4.3<br>Predict the outcome of monohybrid and dihybrid crosses.<br>CLE 3210.4.4<br>Compare different modes of inheritance: sex linkage, co-dominance, incomplete dominance, multiple alleles, and polygenic traits. |
| 12. Describe the processes used in modern biotechnology related to genetic engineering (LS-H-B4) (LS-H-B1)                                     | CLE 3210.4.7<br>Assess the scientific and ethical ramifications of emerging genetic technologies.   |
| 13. Identify possible positive and negative effects of advances in biotechnology (LS-H-B4) (LS-H-B1)   | CLE 3210.4.7<br>Assess the scientific and ethical ramifications of emerging genetic technologies.   |
| 14. Analyze evidence on biological evolution, utilizing descriptions of existing investigations, computer models, and fossil records (LS-H-C1) | CLE 3210.5.4<br>Summarize the supporting evidence for the theory of evolution.  |
| 15. Compare the embryological development of animals in different phyla (LS-H-C1)(LS-H-A3)   | CLE 3210.5.2<br>Analyze the relationship between form and function in living things.  |
| 16. Explain how DNA evidence and fossil records support Darwin's theory of evolution (LS-H-C2)   | CLE 3210.5.2<br>Analyze the relationship between form and function in living things.  |
| 17. Explain how factors affect gene frequency in a population over time (LS-H-C3)  | CLE 3210.5.1<br>Associate structural, functional, and behavioral adaptations with the ability of organisms to survive under various environmental conditions.<br>CLE 3210.5.3   |

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|  | <p>Explain how genetic variation in a population and changing environmental conditions are associated with adaptation and the emergence of new species.<br/>CLE 3210.2.4</p> <p>Describe the sequence of events associated with biological succession.</p>         |
| 18. Classify organisms from different kingdoms at several taxonomic levels, using a dichotomous key (LS-H-C4)                                  | <p>CLE 3210.5.6</p> <p>Explore the evolutionary basis of modern classification systems.</p>  |
| 19. Compare characteristics of the major kingdoms (LS-H-C5)  | <p>CLE 3210.5.6</p> <p>Explore the evolutionary basis of modern classification systems.</p>  |
| 20. Analyze differences in life cycles of selected organisms in each kingdom (LS-H-C6)   | BIOL II CLE*   |
| 21. Compare the structures, functions, and cycles of viruses to those of cells (LS-H-C7)   | BIOL II CLE*   |
| 22. Describe the role of viruses in causing diseases and conditions (e.g., AIDS, common colds, smallpox, influenza, warts) (LS-H-C7) (LS-H-G2) | BIOL II CLE*   |
| 23. Illustrate the flow of carbon, nitrogen, and water through an ecosystem (LS-H-D1) (SE-H-A6)  | <p>CLE 3210.2.3</p> <p>Predict how global climate change, human activity, geologic events, and the introduction of non-native species impact an ecosystem.</p> <p>CLE 3210.3.4</p> <p>Describe the events, which occur during the major biogeochemical cycles.</p> |
| 24. Analyze food webs by predicting the loss or gain of an organism (LS-H-D2)  | <p>CLE 3210.2.1</p> <p>Investigate how the dynamic equilibrium of an ecological community is associated with interactions among its organisms.</p>   |
| 25. Evaluate the efficiency of the flow of energy and matter through a food chain/pyramid (LS-H-D2)  | <p>CLE 3210.3.1</p> <p>Analyze energy flow through an ecosystem.</p>   |
| 26. Analyze the dynamics of a population with and without limiting factors (LS-H-D3)   | <p>CLE 3210.2.2</p> <p>Analyze and interpret population data, graphs, or diagrams.</p>   |
| 27. Analyze positive and negative effects of human actions on ecosystems (LS-H-D4) (SE-H-A7)   | <p>CLE 3210.2.1</p> <p>Investigate how the dynamic equilibrium of an ecological community is associated with interactions among its organisms.</p> <p>CLE 3210.2.4</p>   |

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|  | Describe the sequence of events associated with biological succession.<br>CLE 3210.T/E.4<br>Describe the dynamic interplay among science, technology, and engineering within living, earth-space, and physical systems. |
| 28. Explain why ecosystems require a continuous input of energy from the Sun (LS-H-E1)                           | CLE 3210.2.3<br>Predict how global climate change, human activity, geologic events, and the introduction of non-native species impact an ecosystem.   |
| 29. Use balanced equations to analyze the relationship between photosynthesis and cellular respiration (LS-H-E1) | CLE 3210.3.2<br>Distinguish between aerobic and anaerobic respiration<br>CLE 3210.3.3<br>Investigate the relationship between the processes of photosynthesis and cellular respiration.                                 |
| 30. Explain the role of adenosine triphosphate (ATP) in a cell (LS-H-E2)   | CLE 3210.1.2<br>Distinguish among the structure and function of the four major organic macromolecules found in living things.   |
| 31. Compare the levels of organization in the biosphere (LS-H-E3)  | CLE 3210.2.4<br>Describe the sequence of events associated with biological succession.  |
| 32. Analyze the interrelationships of organs in major systems (LS-H-F1) (LS-H-E3)                                | BIOL II CLE*  |
| 33. Compare structure to function of organs in a variety of organisms (LS-H-F1)                                  | BIOL II CLE*  |
| 34. Explain how body systems maintain homeostasis (LS-H-F2)  | BIOL II CLE*  |
| 35. Explain how selected organisms respond to a variety of stimuli (LS-H-F3)                                     | BIOL II CLE*  |
| 36. Explain how behavior affects the survival of species (LS-H-F4)   | BIOL II CLE*  |
| 37. Explain how fitness and health maintenance can result in a longer human life span (LS-H-G1)                  | BIOL II CLE*  |
| 38. Discuss mechanisms of disease transmission and processes of infection (LS-H-G2) (LS-H-G4)                    | BIOL II CLE*  |

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| 39. Compare the functions of the basic components of the immune system (LS-H-G3)   | BIOL II CLE*  |
| 40. Determine the relationship between vaccination and immunity (LS-H-G3)  | BIOL II CLE*  |
| 41. Describe causes, symptoms, treatments, and preventions of major communicable and noncommunicable diseases (LS-H-G4)                              | BIOL II CLE*  |
| 42. Summarize the uses of selected technological developments related to the prevention, diagnosis, and treatment of diseases or disorders (LS-H-G5) | <p>CLE 3210.4.7<br/>Assess the scientific and ethical ramifications of emerging genetic technologies.</p> <p>CLE 3210.T/E.3<br/>Explain the relationship between the properties of a material and the use of the material in the application of a technology.</p> |

## APPENDIX B: UNIT 1 PRE/POST TEST

# 1

## The Science of Biology

## Unit Test 1

### Multiple Choice

*Write the letter that best answers the question or completes the statement on the line provided.*

- \_\_\_\_ 1. Science differs from other disciplines, such as history and the arts, because science relies on  
a. facts. c. observations.  
b. testing explanations. d. theories.
- \_\_\_\_ 2. Measurements made while observing a plant grow 3 cm over a two-week period are called  
a. inferences. c. hypotheses.  
b. variables. d. data.
- \_\_\_\_ 3. Based on your observations, you suggest that if water is present, it could accelerate the growth of bread mold. This is  
a. a conclusion. c. an experiment.  
b. a hypothesis. d. an analysis.
- \_\_\_\_ 4. Suppose that a scientist proposes a hypothesis about how a newly discovered virus affects humans. Other virus researchers would likely  
a. reject the hypothesis right away.  
b. change the hypothesis to fit their own findings.  
c. design new experiments to test the proposed hypothesis.  
d. assume that the hypothesis is true for all viruses.
- \_\_\_\_ 5. Who reviews articles for peer-reviewed journals?  
a. friends of the scientists who wrote the articles  
b. anonymous and independent experts  
c. the scientists who did the experiments  
d. people who paid for the experiments
- \_\_\_\_ 6. How does sharing ideas through peer-reviewed articles help advance science?  
a. Peer-reviewed articles are published only when the ideas they contain have been accepted by most scientists.  
b. Experiments in peer-reviewed articles do not need to be repeated.  
c. Scientists reading the articles may come up with new questions to study.  
d. Ideas in the articles always support and strengthen dominant theories.
- \_\_\_\_ 7. If a student was doing an experiment on osmosis and she was trying to measure the amount of sugar absorbed into a cell, what tool would she use?  
a. graduated cylinder c. thermometer  
b. triple beam balance d. beaker
- \_\_\_\_ 8. The basic unit of length in the metric system is the  
a. gram. b. liter.

c. yard.

d. meter.

\_\_\_ 9. How many micrometers are in 2.4m?

a. 240

c. 24,000

b. 2,400

d. 240,000

\_\_\_ 10. During a controlled experiment, a scientist isolates and tests

a. a conclusion.

c. a control group.

b. a mass of information.

d. a single variable.

\_\_\_ 11. A student sees a bee on a flower. The student wonders how the bee finds flowers. This student is

a. forming a question.

c. collecting data.

b. forming a conclusion.

d. analyzing results.

\_\_\_ 12. What does a reviewer do during peer-review?

a. Focus on mistakes in spelling.

b. Change data to support results.

c. Check for mistakes and bias.

d. Repeat the experiments in the article.

\_\_\_ 13. A well-tested explanation that explains a lot of observations is

a. a hypothesis.

c. a theory.

b. an inference.

d. a controlled experiment.

\_\_\_ 14. A personal preference or point of view is

a. a bias.

c. a hypothesis.

b. a theory.

d. an inference.

\_\_\_ 15. Scientists often try to repeat each other's results. Which of the following should a scientist do to make it easier for others to replicate his or her experiment?

a. Not use a control to save time.

b. Collect only one set of data.

c. Skip peer-review so the results are available sooner.

d. Use the metric system when communicating procedures and results.

\_\_\_ 16. What is the name of the piece of lab equipment in the picture to the right?

a. beaker

c. glassware

b. graduated cylinder

d. pipette

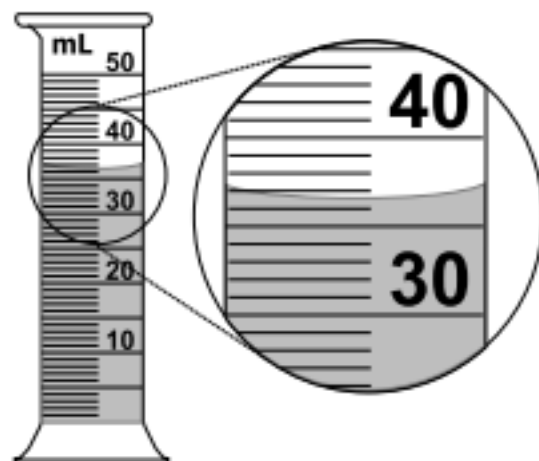
\_\_\_ 17. What is the volume measured in the picture to the right?

a. 36mL

c. 36.5mL

b. 32.5mL

d. 32mL



\_\_\_ 18. What should you do if you spill something in lab?

- a. tell the teacher immediately      c. call 911
  - b. wipe it up      d. hide it so someone else can figure it out
- \_\_\_ 19. When should you wear goggles, gloves, and aprons in lab?
- a. when the teacher tells you to      c. only if dangerous chemicals are used
  - b. anytime glass is used      d. we won't have to so we won't worry about it
- \_\_\_ 20. What is the purpose of a broken glass container?
- a. to store glassware      c. to put broken glassware
  - b. to wash the broken glass      d. to hide the glass from the teacher

**Use the following situation to answer questions 21-25 below.**

Four pea plants were set up under different lights (red, white, blue, and green). Everyday the plants will be watered 50mL and the plant's growth will be recorded in centimeters. Data will be collected everyday at for 2 weeks.

- \_\_\_ 21. From the lab setup described above, what would the scientist's independent variable be?
- a. the growth of the plants      c. the different colored light
  - b. the amount of water      d. the plant growing in the white light
- \_\_\_ 22. From the lab setup described above, what would the scientist's dependent variable be?
- a. the growth of the plants      c. the different colored light
  - b. the amount of water      d. the plant growing in the white light
- \_\_\_ 23. From the lab setup described above, what would be a constant in this experiment?
- a. the growth of the plants      c. the different colored light
  - b. the amount of water      d. the plant growing in the white light
- \_\_\_ 24. From the lab setup described above, which plant would act as a control?
- a. the plant growing in the blue light      c. the plant growing in the red light
  - b. there is no control      d. the plant growing in the white light
- \_\_\_ 25. From the lab setup described above, what is the most likely hypothesis of the scientist?
- a. If light affects plant growth, then the plant with the most light will grow the most.
  - b. If light affects plant growth, then the plant with the most light will grow the least.
  - c. If the color of light affects plant growth, then the plant with green light will grow the most.
  - d. If a plant's growth affects the color of light, then the plant with green light will grow the most.



**Use the following data to answer questions 26-30 below.**

One of the best-known examples of a population study came from the records of a fur-trading company in Canada. The Hudson's Bay Company (HBC) kept records of its catches of hare and lynx over a long period of time. Charles Elton, an English ecologist, used the records to hypothesize about cycles in animal populations. The table shows the HBC data for hares and lynx pelts taken between 1845 and 1899.

| Comparison of HBC Hare and Lynx Pelts |      |      |      |      |      |
|---------------------------------------|------|------|------|------|------|
| Year                                  | Hare | Lynx | Year | Hare | Lynx |
| 1845                                  | 20   | 32   | 1873 | 70   | 20   |
| 1847                                  | 20   | 50   | 1875 | 100  | 34   |
| 1849                                  | 52   | 12   | 1877 | 92   | 45   |
| 1851                                  | 83   | 10   | 1879 | 70   | 40   |
| 1853                                  | 64   | 13   | 1881 | 10   | 15   |
| 1855                                  | 68   | 36   | 1883 | 11   | 15   |
| 1857                                  | 83   | 15   | 1885 | 137  | 60   |
| 1859                                  | 12   | 12   | 1887 | 137  | 80   |
| 1861                                  | 36   | 6    | 1889 | 18   | 26   |
| 1863                                  | 150  | 6    | 1891 | 22   | 18   |
| 1865                                  | 110  | 65   | 1893 | 52   | 37   |
| 1867                                  | 60   | 70   | 1895 | 83   | 50   |
| 1869                                  | 7    | 40   | 1897 | 18   | 35   |
| 1871                                  | 10   | 9    | 1899 | 10   | 12   |

- \_\_\_\_ 26. From the data described above, what would the independent variable be?
- a. the years the study took place      c. the number of pelts for hare and lynx  
b. the population      d. the HBC records
- \_\_\_\_ 27. From the data described above, what data would go on the vertical axis?
- a. the years the study took place      c. the number of pelts for hare and lynx  
b. the population      d. the HBC records
- \_\_\_\_ 28. From the data described above, what would be the best graph to display this data?
- a. bar graph      c. line graph  
b. pie chart      d. double line graph
- \_\_\_\_ 29. From the data described above, what would be the best title for the data set?
- a. Number of hare and lynx pelts from 1845 to 1899  
b. HBC Records  
c. Hare and lynx population  
d. Data from 1845 to 1988
- \_\_\_\_ 30. The data above was used to hypothesize what?
- a. the productivity of fur trading      c. the number of all animals in a Canadian forest  
b. the cycles in animal populations      d. the mating patterns of hares with lynx

## Using Science Skills

Use the diagram below to answer the following questions on the lines provided.

A scientist conducted an experiment to determine the effect of environment on the fur color of a Himalayan rabbit. The Himalayan rabbit typically has a white coat except for its colder nose, feet, tail, and ears, which are black. The scientist shaved an area of hair on the back of each rabbit, then placed an ice pack over the shaved area on one rabbit (A).

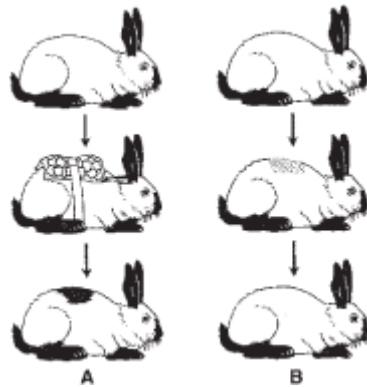


Figure 1–1

**31. Interpret Visuals** In Figure 1–1, which rabbit is the control?

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**32. Interpret Visuals** In Figure 1–1, what is the variable in this experiment?

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**33. Form a Hypothesis** Before completing the experiment in Figure 1–1, the scientist made a hypothesis. What is the hypothesis she is testing?

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**34. Apply Concepts** Why is Rabbit B essential to the experiment in Figure 1–1?

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**35. Draw Conclusions** Based on your observations of Figure 1–1, conclude what effect temperature has on Himalayan rabbits.

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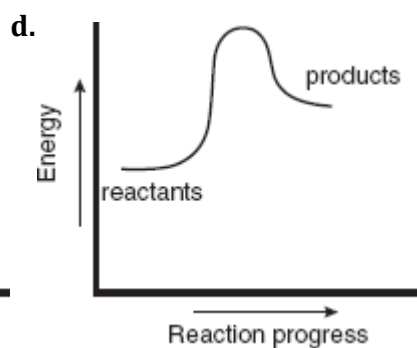
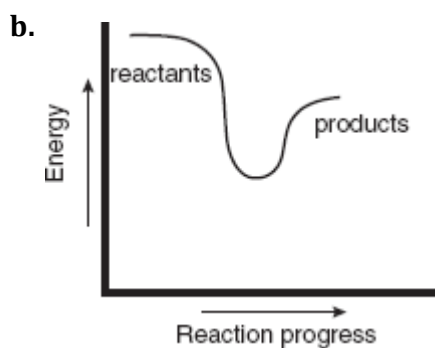
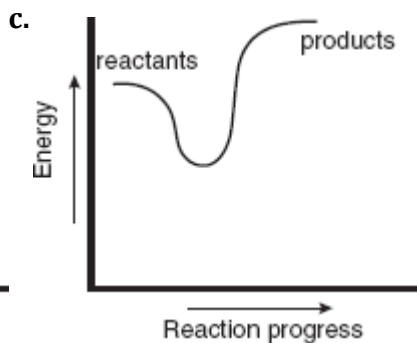
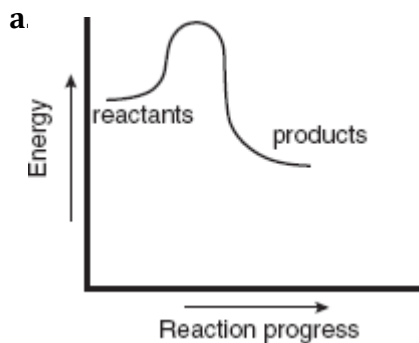
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## Unit 2 Test

### Multiple Choice

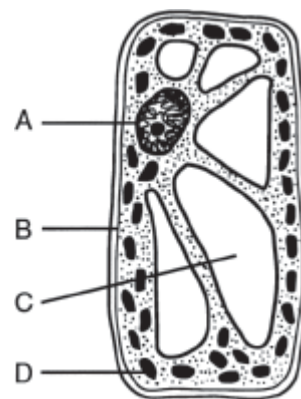
Write the letter that best answers the question or completes the statement on the line provided.

- \_\_\_ 1. Which of the following makes up a molecule of water?
- one atom of hydrogen and one atom of oxygen
  - one atom of sodium and one atom of chlorine
  - one atom of hydrogen and two atoms of oxygen
  - two atoms of hydrogen and one atom of oxygen
- \_\_\_ 2. A substance with a pH of 6 is called
- an acid.
  - a base.
  - water.
  - a suspension.
- \_\_\_ 3. Amino acid is to protein as
- fat is to lipid.
  - DNA is to RNA.
  - sugar is to fat.
  - simple sugar is to starch.
- \_\_\_ 4. Which of the following diagrams correctly shows the reaction pathway of a reaction that absorbs energy?



- \_\_\_ 5. Which of the following statements about enzymes is NOT true?
- Enzymes work best at a specified pH.
  - All enzymes have the same shape as their substrates.
  - Enzymes are proteins.
  - The shape of an enzyme allows it to do its job.

- \_\_\_ 6. A map of eastern North America, showing the pH of rainfall in the various states, indicates that the pH of rain in New York State varies from 4.22 to 4.40. According to these figures, the most acidic rainfall in New York State has a pH of
- 4.22
  - 4.30
  - 4.35
  - 4.40
- \_\_\_ 7. Identify the reactant(s) shown here:  $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$ .
- $\text{CO}_2$ ,  $\text{H}_2\text{O}$ , and  $\text{H}_2\text{CO}_3$
  - $\text{CO}_2$  and  $\text{H}_2\text{O}$
  - $\text{H}_2\text{CO}_3$
  - $\text{CO}_2$
- \_\_\_ 8. The energy needed to get a reaction started is the
- adhesion energy.
  - activation energy.
  - cohesion energy.
  - chemical energy.
- \_\_\_ 9. Which of the following statements is true about catalysts?
- Catalysts slow down the rate of chemical reactions.
  - All catalysts are enzymes.
  - Catalysts are used up during a chemical reaction.
  - Catalysts lower the activation energy of a chemical reaction.
- \_\_\_ 10. Looking at a cell under a microscope, you note that it is a prokaryote. How do you know?
- The cell lacks cytoplasm.
  - The cell lacks a cell membrane.
  - The cell lacks a nucleus.
  - The cell lacks genetic material.
- \_\_\_ 11. Which of the following is NOT found in the nucleus?
- mitochondria.
  - nucleolus
  - chromatin
  - DNA
- \_\_\_ 12. Which organelle breaks down organelles that are no longer useful?
- Golgi apparatus
  - lysosome
  - endoplasmic reticulum
  - mitochondrion
- \_\_\_ 13. Which structure in the cell shown in Figure 7-1 above stores materials, such as water, salts, proteins, and carbohydrates?
- structure A
  - structure B
  - structure C
  - structure D
- \_\_\_ 14. Which sequence correctly traces the path of a protein in the cell?
- ribosome, endoplasmic reticulum, Golgi apparatus
  - ribosome, endoplasmic reticulum, chloroplast
  - endoplasmic reticulum, lysosome, Golgi apparatus
  - ribosome, Golgi apparatus, endoplasmic reticulum
- \_\_\_ 15. Which organelle converts the chemical energy stored in food into useable energy?
- chloroplast
  - Golgi apparatus
  - endoplasmic reticulum
  - mitochondrion
- \_\_\_ 16. Which of the following is a function of the cell membrane?

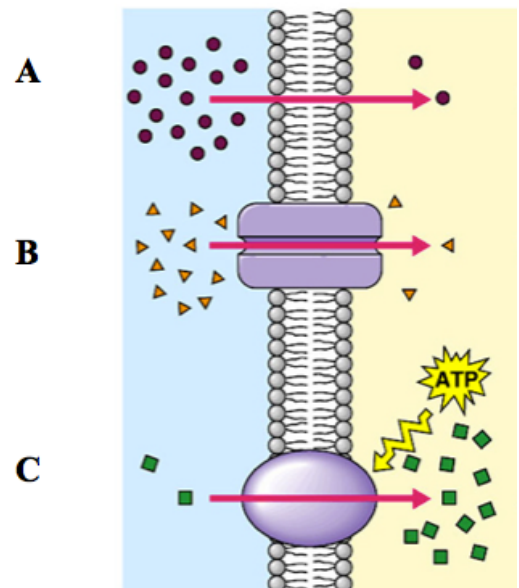


- a. breaks down lipids, carbohydrates, and proteins from foods
- b. stores water, salt, proteins, and carbohydrates
- c. keeps the cell wall in place
- d. regulates the movement of materials into and out of the cell

- \_\_\_ 17. The cell membrane contains channels and pumps that help move materials from one side to the other. What are these channels and pumps made of?
- a. carbohydrates
  - b. lipids
  - c. bilipids
  - d. proteins
- \_\_\_ 18. Diffusion occurs because
- a. molecules are attracted to one another.
  - b. molecules move and collide with each other forcing them to low concentrations
  - c. cellular energy forces molecules to collide with each other.
  - d. cellular energy pumps molecules across the cell membrane.
- \_\_\_ 19. An animal cell that is surrounded by fresh water will burst because the osmotic pressure causes
- a. water to move into the cell.
  - b. water to move out of the cell.
  - c. solutes to move into the cell.
  - d. solutes to move out of the cell.
- \_\_\_ 20. You decide to buy a new fish for your freshwater aquarium. When you introduce the fish into its new tank, the fish swells up and dies. You later learn that it was a fish from the ocean. Based on what you know of tonicity, the most likely explanation is that unfortunate fish went from a(n) \_\_\_\_\_ solution into a(n) \_\_\_\_\_ solution.
- a. isotonic, hypotonic
  - b. hypertonic, isotonic
  - c. hypotonic, hypertonic
  - d. hypotonic, isotonic

**Use Figure 7-2 to answer questions 21 - 25 below.**

- \_\_\_ 21. Which of the following diagrams represents active transport?
- a. A
  - b. B
  - c. C
  - d. A and B
- \_\_\_ 22. Facilitated diffusion moves particles from \_\_\_ to \_\_\_ concentration.
- a. high, low
  - b. low, high
  - c. high, high
  - d. low, low



- \_\_\_ 23. Diagram B represents
- diffusion
  - active transport
  - osmosis
  - facilitated diffusion
- \_\_\_ 24. Which means of particle transport requires input of energy from the cell?
- diffusion
  - osmosis
  - facilitated diffusion
  - active transport
- \_\_\_ 25. In osmosis, what molecule is being transported?
- CO<sub>2</sub>
  - K
  - H<sub>2</sub>O
  - ATP

### Using Science Skills

Use the diagram below to answer the following questions on the lines provided.

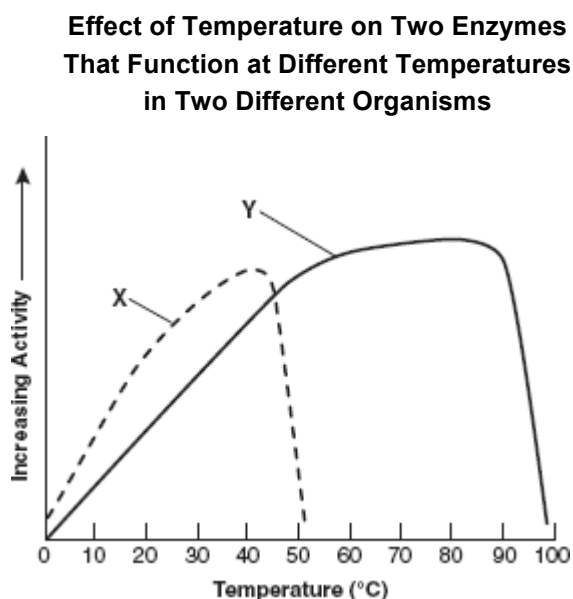


Figure 7-3

- \_\_\_ 26. Which enzyme would you expect to find in a bacterium growing in a hot spring?
- Enzyme X
  - Enzyme Y
  - Both enzymes X and Y
  - No enzymes would be found in bacteria from a hot spring.
- \_\_\_ 27. At what temperature do the two enzymes have the same amount of activity?
- 0° C
  - 45° C
  - 50° C
  - 60° C
- \_\_\_ 28. What are the optimum temperatures for each enzyme (X and Y)?
- 0° C and 0° C
  - 50° C and 50° C
  - 40° C and 80° C
  - 0° C and 100° C
- \_\_\_ 29. Which enzyme would have the most activity in humans?
- Enzyme X
  - Enzyme Y
  - Both enzymes X and Y
  - Enzymes are not found in humans.
- \_\_\_ 30. Which enzyme is active over the largest temperature range?

- a. Enzyme X
- b. Enzyme Y

- c. Both enzymes X and Y
- d. No enzymes are ever active

### Using Science Skills

Use the diagram below to answer the following questions on the lines provided.

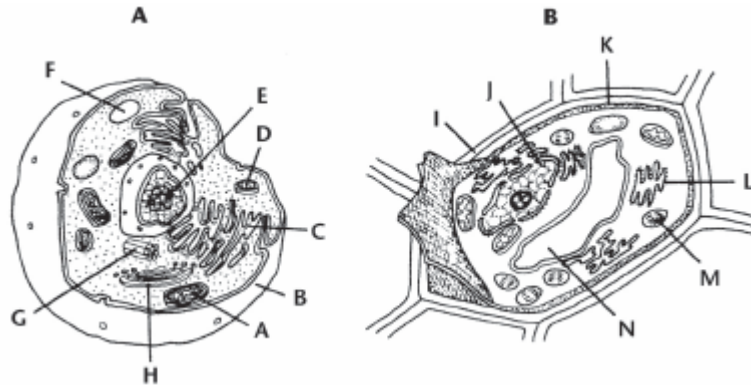


Figure 7-4

**31. Interpret Visuals** Which drawing in Figure 7-4, A or B, contains structures that carry out photosynthesis? What is this structure labeled in the diagram?

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**32. Interpret Visuals** Which organelle is labeled K in Figure 7-4? What is the function of this organelle?

---



---

**33. Draw Conclusions** Do the drawings in Figure 7-4 represent prokaryotes or eukaryotes? How do you know?

---

**34. Apply Concepts** I forgot to water my plants for 3 days and they began to sag. What happened to the vacuole in the plant cell? Why did it sag? Diagram and label this.

**35. Extend** For each of the following, indicate if the structure is found only in eukaryotes, or if it is found in eukaryotes and prokaryotes:

| Organelle       | Prokaryotes | Eukaryotes |
|-----------------|-------------|------------|
| Cell Membrane   |             |            |
| Mitochondria    |             |            |
| Ribosomes       |             |            |
| Golgi Apparatus |             |            |
| Nucleus         |             |            |
| Cytoplasm       |             |            |
| DNA             |             |            |

# 3 Photosynthesis & Cell Respiration

## Unit 3 Test

### Multiple Choice

Write the letter that best answers the question or completes the statement on the line provided.

- \_\_\_\_ 1. What are the three parts of an ATP molecule?
  - a. adenine, thylakoid, and a phosphate group
  - b. stroma, grana, and chlorophyll
  - c. adenine, ribose, and three phosphate groups
  - d. NADH, NADPH, and FADH<sub>2</sub>
- \_\_\_\_ 2. Energy is released from ATP when
  - a. a phosphate group is added.
  - b. adenine bonds to ribose.
  - c. ATP is exposed to sunlight.
  - d. a phosphate group is removed.
- \_\_\_\_ 3. Organisms, such as plants, that make their own food are called
  - a. autotrophs.
  - b. heterotrophs.
  - c. thylakoids.
  - d. pigments.
- \_\_\_\_ 4. Which of the following organisms is a heterotroph?
  - a. mushroom
  - b. alga
  - c. wheat
  - d. sunflower
- \_\_\_\_ 5. Plants get the energy they need for photosynthesis by absorbing
  - a. high-energy sugars.
  - b. chlorophyll a.
  - c. chlorophyll b.
  - d. energy from the sun.
- \_\_\_\_ 6. Most plants appear green because chlorophyll
  - a. absorbs green light.
  - b. absorbs violet light.
  - c. does not absorb green light.
  - d. does not absorb violet light.
- \_\_\_\_ 7. The stroma is the region outside the
  - a. thylakoids.
  - b. chloroplasts.
  - c. plant cells.
  - d. all of the above
- \_\_\_\_ 8. Where in the chloroplast is chlorophyll found?
  - a. in the ATP
  - b. in the stroma
  - c. in the thylakoid membrane
  - d. in the thylakoid space
- \_\_\_\_ 9. What is the function of NADP<sup>+</sup> in photosynthesis?
  - a. electron carrier
  - b. high-energy sugar
  - c. photosystem
  - d. pigment
- \_\_\_\_ 10. Photosynthesis uses sunlight to convert water and carbon dioxide into
  - a. oxygen and carbon.
  - b. high-energy sugars and proteins.
  - c. ATP and oxygen.
  - d. oxygen and high-energy sugar
- \_\_\_\_ 11. Where do the light-dependent reactions take place?
  - a. in the stroma of the chloroplast
  - b. within the mitochondria membranes
  - c. within the thylakoid membranes



- d.** in the outer membrane of the chloroplasts
- \_\_\_ **12.** What are the products of the light-dependent reactions?
- oxygen gas and glucose
  - ATP, NADPH, and oxygen gas
  - ATP, carbon dioxide gas, and NADPH
  - carbon dioxide gas, oxygen gas, and NADPH
- \_\_\_ **13.** Where are photosystems I and II found?
- in the stroma
  - in the thylakoid membrane
  - in the Calvin cycle.
  - in the cell membrane
- \_\_\_ **14.** Which of the following activities happens within the stroma?
- Photosystem I absorbs light.
  - ATP synthase produces ATP.
  - The Calvin cycle produces sugars.
  - Electrons move through the electron transport chain.
- \_\_\_ **15.** The Calvin cycle is another name for the
- light-independent reactions.
  - light-dependent reactions.
  - photosynthesis reaction.
  - electron transport chain.
- \_\_\_ **16.** Which chemical equation represents cell respiration?
- $\text{light} + 6\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6$
  - $\text{light} + \text{H}_2\text{O} + 6\text{CO}_2 \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$
  - $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{H}_2\text{O} + 6\text{CO}_2$
  - $\text{C}_6\text{H}_{12}\text{O}_6 + \text{H}_2\text{O} + 6\text{CO}_2 \rightarrow \text{light} + 6\text{O}_2$
- \_\_\_ **17.** How do organisms get the energy they need?
- by burning food molecules and releasing their energy as heat
  - by breathing oxygen into the lungs and combining it with carbon dioxide
  - by breaking down food molecules gradually and capturing their chemical energy
  - by using the sun's energy to break down food molecules and form chemicals
- \_\_\_ **18.** Which of the following is NOT a stage of cellular respiration?
- fermentation
  - electron transport
  - glycolysis
  - Krebs cycle
- \_\_\_ **19.** Cellular respiration is called an aerobic process because it requires
- light.
  - exercise.
  - oxygen.
  - glucose.
- \_\_\_ **20.** Photosynthesis is to chloroplasts as cellular respiration is to
- chloroplasts.
  - cytoplasm.
  - mitochondria.
  - nuclei.
- \_\_\_ **21.** The products of photosynthesis are the
- products of cellular respiration.
  - reactants of cellular respiration.
  - products of glycolysis.

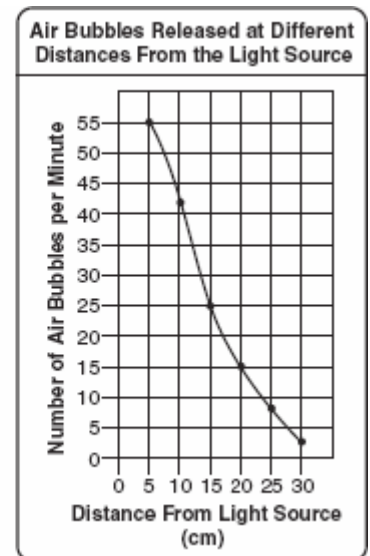
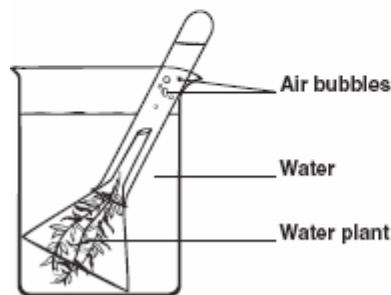
d. reactants of fermentation.

- \_\_\_ 22. Glycolysis provides a cell with a net gain of  
a. 2 ATP molecules. c. 18 ATP molecules.  
b. 4 ATP molecules. d. 36 ATP molecules.
- \_\_\_ 23. Glycolysis requires  
a. ATP. c. sunlight.  
b. oxygen. d. NADP<sup>+</sup>.
- \_\_\_ 24. In eukaryotes, electron transport occurs in the  
a. inner mitochondrial membrane. c. cell membrane.  
b. nucleus. d. cytoplasm.
- \_\_\_ 25. Cellular respiration uses 1 molecule of glucose to produce approximately  
a. 2 ATP molecules. c. 32 ATP molecules.  
b. 4 ATP molecules. d. 36 ATP molecules.

### Using Science Skills

Use the figure to answer the following questions on the lines provided.

A student prepared two beakers with identical sprigs of a water plant as shown below. She placed one beaker in the shade and the other beaker beside a fluorescent lamp. She then systematically changed the distance from the beaker to the lamp. She counted the bubbles given off by the plants in each beaker. Shown here is the graph of the data for the beaker she placed beside the lamp.



- \_\_\_ 26. In the experiment described in Figure 8-2, which beaker is the student's control?  
a. beaker in the shade c. beaker 10 cm from the light  
b. beaker 0 cm from the light d. beaker 30 cm from the light
- \_\_\_ 27. Look at Figure 8-2. If the student later tested the bubbles collected in the test tube, what would she find they are made of?  
a. CO<sub>2</sub> c. O<sub>2</sub>  
b. H<sub>2</sub>O d. C<sub>6</sub>H<sub>12</sub>O<sub>6</sub>
- \_\_\_ 28. Look at the graph in Figure 8-2. At what distance from the light source was the greatest number of bubbles produced?  
a. 5 c. 15  
b. 10 d. 20
- \_\_\_ 29. Which chemical equation represents photosynthesis?

- a.  $\text{light} + 6\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6$
- b.  $\text{light} + \text{H}_2\text{O} + 6\text{CO}_2 \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$
- c.  $\text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2 \rightarrow 6\text{H}_2\text{O} + 6\text{CO}_2$
- d.  $\text{C}_6\text{H}_{12}\text{O}_6 + \text{H}_2\text{O} + 6\text{CO}_2 \rightarrow \text{light} + 6\text{O}_2$

30. Look at the graph in Figure 8–2. What do the student’s data show?

- a. The closer the plant is to the light source the lower the rate of photosynthesis.
- b. The further the plant is away from light source the higher the rate of photosynthesis.
- c. The closer the plant is to the light source the higher the rate of photosynthesis.
- d. There is no relationship between the light and the rate of photosynthesis.

### Short Answer

*In complete sentences, write the answers to the questions on the lines provided.*

31. Figure 9–1 shows how energy flows among the sun, plants, animals, and fossil fuels. Which arrow represents cellular respiration? Explain your reasoning.

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32. What roles does oxygen play in photosynthesis and in cellular respiration?

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33. The electron transport chain uses the energy stored in high-energy electrons to pump  $\text{H}^+$  ions across the inner mitochondrial membrane. Why?

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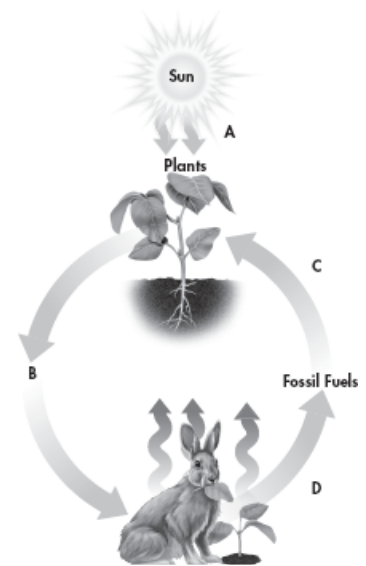


Figure 9–1

34. What role does oxygen play in the electron transport chain?

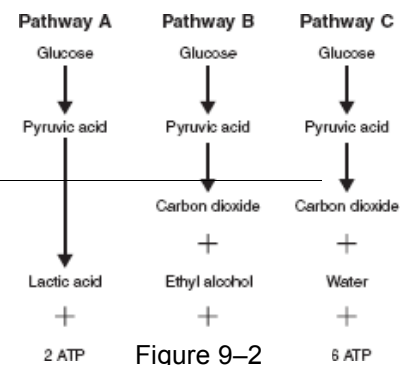
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35. Given the inefficiency of two of the pathways shown in Figure 9–2, what advantage could there be to using these pathways to produce energy?

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## APPENDIX E: UNIT EXAM QUESTION ALIGNMENT

Question alignment of each unit exam to the Louisiana GLEs for Biology

### Alignment to Louisiana Biology Grade Level Expectations: Unit 1

| <b>Question</b> | <b>GLE</b>      | <b>Question (cont.)</b> | <b>GLE (cont.)</b> |
|-----------------|-----------------|-------------------------|--------------------|
| 1               | SI-H-B1 #11     | 19                      | SI-H-A7 #10        |
| 2               | SI-H-A2 #3      | 20                      | SI-H-A7 #10        |
| 3               | SI-H-A1 #1      | 21                      | SI-H-A2 #3         |
| 4               | SI-H-B2 #13     | 22                      | SI-H-A2 #3         |
| 5               | SI-H-B1,4,5 #16 | 23                      | SI-H-A2 #3         |
| 6               | SI-H-B1,4,5 #16 | 24                      | SI-H-A2 #3         |
| 7               | SI-H-A3 #6      | 25                      | SI-H-A1 #1         |
| 8               | SI-H-A3 #6      | 26                      | SI-H-A2 #3         |
| 9               | SI-H-A3 #6      | 27                      | SI-H-A3 #5         |
| 10              | SI-H-A2 #3      | 28                      | SI-H-A3 #5         |
| 11              | SI-H-A1 #1      | 29                      | SI-H-A3 #5         |
| 12              | SI-H-B1,4,5 #16 | 30                      | SI-H-A1 #1         |
| 13              | SI-H-B1 #11     | 31                      | SI-H-A2 #3         |
| 14              | SI-H-B1 #11     | 32                      | SI-H-A2 #3         |
| 15              | SI-H-A2 #3      | 33                      | SI-H-A1 #1         |
| 16              | SI-H-A2 #3      | 34                      | SI-H-A2 #3         |
| 17              | SI-H-A3 #6      | 35                      | SI-H-A2 #9         |
| 18              | SI-H-A7 #10     |                         |                    |

### Alignment to Louisiana Biology Grade Level Expectations: Unit 2

| <b>Question</b> | <b>GLE</b> | <b>Question (cont.)</b> | <b>GLE (cont.)</b> |
|-----------------|------------|-------------------------|--------------------|
| 1               | LS-H-A1 #3 | 19                      | LS-H-A2 #4         |
| 2               | LS-H-A1 #3 | 20                      | LS-H-A2 #5         |
| 3               | LS-H-A1 #2 | 21                      | LS-H-A2 #4         |
| 4               | LS-H-A1 #3 | 22                      | LS-H-A2 #4         |
| 5               | LS-H-A1 #3 | 23                      | LS-H-A2 #4         |
| 6               | LS-H-A1 #3 | 24                      | LS-H-A2 #4         |
| 7               | LS-H-A1 #3 | 25                      | LS-H-A2 #4         |
| 8               | LS-H-A1 #3 | 26                      | SI-H-A3 #5         |
| 9               | LS-H-A1 #3 | 27                      | SI-H-A3 #5         |
| 10              | LS-H-A1 #1 | 28                      | SI-H-A3 #5         |
| 11              | LS-H-A1 #2 | 29                      | SI-H-B4 #15        |
| 12              | LS-H-A1 #2 | 30                      | SI-H-B4 #15        |
| 13              | LS-H-A1 #2 | 31                      | LS-H-A1 #2         |
| 14              | LS-H-A1 #2 | 32                      | LS-H-A1 #2         |
| 15              | LS-H-A1 #2 | 33                      | LS-H-A1 #1         |
| 16              | LS-H-A1 #2 | 34                      | LS-H-A2 #5         |
| 17              | LS-H-A1 #2 | 35                      | LS-H-A1 #2         |
| 18              | LS-H-A2 #4 |                         |                    |

Alignment to Louisiana Biology Grade Level Expectations: Unit 3

| <b>Question</b> | <b>GLE</b>  | <b>Question (cont.)</b> | <b>GLE (cont.)</b> |
|-----------------|-------------|-------------------------|--------------------|
| 1               | LS-H-E2 #30 | 19                      | LS-H-E1 #29        |
| 2               | LS-H-E2 #30 | 20                      | LS-H-A1 #2         |
| 3               | LS-H-D2 #25 | 21                      | LS-H-E1 #29        |
| 4               | LS-H-D2 #25 | 22                      | LS-H-E2 #30        |
| 5               | LS-H-E1 #28 | 23                      | SE-H-A6 #23        |
| 6               | LS-H-E1 #29 | 24                      | LS-H-A1 #2         |
| 7               | LS-H-E1 #29 | 25                      | LS-H-E2 #30        |
| 8               | LS-H-E1 #29 | 26                      | SI-H-A2 #3         |
| 9               | LS-H-E1 #29 | 27                      | SI-H-A2 #3         |
| 10              | LS-H-E1 #29 | 28                      | SI-H-A3 #5         |
| 11              | LS-H-A1 #2  | 29                      | LS-H-E1 #29        |
| 12              | LS-H-E1 #29 | 30                      | SI-H-A2,6 #9       |
| 13              | LS-H-A1 #2  | 31                      | LS-H-E1 #29        |
| 14              | LS-H-A1 #2  | 32                      | LS-H-E1 #29        |
| 15              | LS-H-E1 #29 | 33                      | LS-H-E2 #30        |
| 16              | LS-H-E1 #29 | 34                      | LS-H-E1 #29        |
| 17              | LS-H-E1 #28 | 35                      | LS-H-E1 #29        |
| 18              | LS-H-E1 #29 |                         |                    |

## APPENDIX F: ENGAGEMENT SURVEY

### 1. Between August and December, what type of notes did you take?

- ☐ electronic (computer)
- ☐ traditional (pencil & paper)

### 2. When taking notes in a single class period, how often...

|  | 0 times               | 1-5 times             | 6-10 times            | 11-15 times           | 15+ times             |
|--|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| were you on a different webpage?                   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| were you doing something that wasn't taking notes? | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| were "zoned out" or not paying attention           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

### 3. When taking notes during a single class period, how many minutes...

|  | 0 minutes             | 1-3 minutes           | 4-7 minutes           | 8-10 minutes          | more than 10 minutes  |
|--|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| did you spend off-task                                 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| were you on a different page or screen (not the notes) | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| "zoned out" or not paying attention                    | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

**\* 1. Which type of notes did you take?**

**\* 2. What grades do you normally make in Biology?**

☐ A

☐ B

☐ C

☐ D

☐ F

**3. Are you male or female?**

☐ Male

☐ Female

**4. Are you White, Black or African-American, American Indian or Alaskan Native, Asian, Native Hawaiian or other Pacific islander, or some other race?**

☐ White

☐ Black or African-American

☐ American Indian or Alaskan Native

☐ Asian

☐ Native Hawaiian or other Pacific Islander

☐ From multiple races

Some other race (please specify)

**\* 5. Evaluate the following statements.**

|   | Electronic Note-taking | Traditional Note-taking | Both Electronic and Traditional Note-taking | Neither Electronic or Traditional Note-taking | I'm not sure          |
|---|------------------------|-------------------------|---|---|-----------------------|
| I feel note taking is easiest when using...       | <input type="radio"/>  | <input type="radio"/>   | <input type="radio"/>                       | <input type="radio"/>                         | <input type="radio"/> |
| I feel like note taking takes the longest when... | <input type="radio"/>  | <input type="radio"/>   | <input type="radio"/>                       | <input type="radio"/>                         | <input type="radio"/> |
| I feel like I learn the most when...              | <input type="radio"/>  | <input type="radio"/>   | <input type="radio"/>                       | <input type="radio"/>                         | <input type="radio"/> |
| I prefer...                                       | <input type="radio"/>  | <input type="radio"/>   | <input type="radio"/>                       | <input type="radio"/>                         | <input type="radio"/> |
| I learn more from...                              | <input type="radio"/>  | <input type="radio"/>   | <input type="radio"/>                       | <input type="radio"/>                         | <input type="radio"/> |
| I am most distracted when...                      | <input type="radio"/>  | <input type="radio"/>   | <input type="radio"/>                       | <input type="radio"/>                         | <input type="radio"/> |
| My grades are better when I use...                | <input type="radio"/>  | <input type="radio"/>   | <input type="radio"/>                       | <input type="radio"/>                         | <input type="radio"/> |

**\* 6. Answer the following questions based on the total amount of time you spend studying.**

How many minutes do you spend studying for a unit exam?

How many minutes do you spend studying notes/activities from your binder?

How many minutes do you spend studying notes/activities from your computer?

**\* 7. Explain how you feel about the method of note-taking you were required to do in class.**



## APPENDIX G: IRB APPROVAL

### ACTION ON EXEMPTION APPROVAL REQUEST



Institutional Review Board  
Dr. Dennis Landin, Chair  
130 David Boyd Hall  
Baton Rouge, LA 70803  
P: 225.578.8692  
F: 225.578.5983  
[irb@lsu.edu](mailto:irb@lsu.edu) | [lsu.edu/irb](http://lsu.edu/irb)

**TO:** Chelsea Duhon  
Biological Sciences

**FROM:** Dennis Landin  
Chair, Institutional Review Board

**DATE:** June 16, 2014  
**RE:** IRB# E8824

**TITLE:** Traditional versus electronic: The impacts of the mode of note taking on student engagement and achievement in a high school science classroom

**New Protocol/Modification/Continuation:** New Protocol

**Review Date:** 6/13/2014

**Approved** X **Disapproved** \_\_\_\_\_

**Approval Date:** 6/13/2014 **Approval Expiration Date:** 6/12/2017

**Exemption Category/Paragraph:** 1

**Signed Consent Waived?:** No

**Re-review frequency:** (three years unless otherwise stated)

**LSU Proposal Number (if applicable):** \_\_\_\_\_

**Protocol Matches Scope of Work in Grant proposal: (if applicable)** \_\_\_\_\_

**By:** Dennis Landin, Chairman 

**PRINCIPAL INVESTIGATOR: PLEASE READ THE FOLLOWING –**  
**Continuing approval is CONDITIONAL on:**

1. Adherence to the approved protocol, familiarity with, and adherence to the ethical standards of the Belmont Report, and LSU's Assurance of Compliance with DHHS regulations for the protection of human subjects\*
2. Prior approval of a change in protocol, including revision of the consent documents or an increase in the number of subjects over that approved.
3. Obtaining renewed approval (or submittal of a termination report), prior to the approval expiration date, upon request by the IRB office (irrespective of when the project actually begins); notification of project termination.
4. Retention of documentation of informed consent and study records for at least 3 years after the study ends.
5. Continuing attention to the physical and psychological well-being and informed consent of the individual participants, including notification of new information that might affect consent.
6. A prompt report to the IRB of any adverse event affecting a participant potentially arising from the study.
7. Notification of the IRB of a serious compliance failure.
8. SPECIAL NOTE:

*\*All investigators and support staff have access to copies of the Belmont Report, LSU's Assurance with DHHS, DHHS (45 CFR 46) and FDA regulations governing use of human subjects, and other relevant documents in print in this office or on our World Wide Web site at <http://www.lsu.edu/irb>*

## **VITA**

Chelsea Ann Duhon, native of Lutcher, Louisiana, received her Bachelors of Science at Louisiana State University in 2012. Immediately following graduation she was hired by Iberville Parish School Board to teach at the Mathematics, Science, and Arts Academy-West, a National Magnet School of Distinction. There she has taught 6<sup>th</sup> grade Physical Science, 7<sup>th</sup> grade Life Science, Biology, and Environmental Science, and she has coordinated the school and district science fair each year. She is a current sponsor of the science club, the Knights of the Periodic Table, and she is the head swimming coach for Plaquemine High School. She is a 2015 candidate for the Master of Natural Science degree from Louisiana State University, and plans to pursue employment at a local community college upon graduation.